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DEMONSTRATION AND EVALUATION OF RECENT AIR-SEALING TECHNIQUES IN HOUSING

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Prepared by:

William J. Mayhew, P. Eng.
Howell Mayhew Engineering, Inc.

The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

The Program offers assistance to builders, developers, consulting firms, professionals, industry groups, building products manufacturers, municipal governments, educational institutions, non-profit groups and individuals. At this time, priority areas for investigation include building design, construction technology, energy conservation, site and subdivision design, site servicing technology, residential building product development or improvement and information technology.

As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied. Comments and suggestions on this report are welcome. Please send comments or requests for further information to:

Innovative Housing Grants Program
Alberta Municipal Affairs
9925 - 107th Street
Edmonton, Alberta
T5K 2H9

Telephone: (403) 427-8150

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EXECUTIVE SUMMARY

The Airtight Drywall Approach (ADA) and the sealed polyethylene approach were developed as two distinct systems for reducing air leakage in housing. Each system has been used with varying degrees of success. Builders have not totally accepted either method but have instead tended to borrow the most practical and cost-effective techniques and materials from each system and combined them into hybrid systems. These air-sealing systems continue to be refined in an attempt to simplify their installation and to develop a system that will interfere as little as possible with the normal work of the other trades. Air-sealing systems are emerging that can be installed in one trip by a single trade.

In addition to refining installation techniques, builders are experimenting with many different products to achieve an effective and durable air barrier and vapour retarder. The long-term durability of many of the materials, and therefore, the effectiveness of the air seal, remains in question, and additional testing and evaluation is recommended.

Experienced and knowledgeable builders and tradespeople are the key to successful air-sealing. This experience is often not available, however, so techniques must be kept simple for installation by as few trades as possible. This project evaluated current air-sealing techniques, developed refinements to some of those techniques and incorporated them into the construction of the Cold Climate Demonstration House (CCDH), a research and demonstration facility operated by Howell Mayhew Engineering.

By comparing the effectiveness and practical use of different air and vapour retarder materials and techniques, it was found that, for the air barrier, ADA materials and techniques were more easily installed. The resulting air seal was more reliable. However, until inspectors accept alkyd or vapour barrier paints as the vapour retarder, polyethylene is recommended. The construction techniques recommended in this report can be installed with a minimum of experience and with minimal involvement of other subtrades. The cost to provide an air/vapour barrier for a 1000 ft2 bilevel with both levels fully developed (as demonstrated in the CCDH) was approximately $360.

As building envelope airtightness increases the amount of natural airchange that the house experiences decreases and there is a greater potential for problems such as condensation, backdrafting and spillage of combustion appliances and the concentration of indoor air pollutants. Such problems can be successfully dealt with, however, by installing a controlled ventilation system and combustion appliances that are uncoupled from the effects of indoor air pressures. The technology to solve these problems is available but expensive. The high incremental cost of providing ventilation systems and induced draft or sealed combustion appliances are a major factor in reducing the builder's incentive to provide well-sealed housing.

1.0 INTRODUCTION

As energy-efficient housing technology developed, two distinct air-sealing systems have evolved to control air leakage and vapour diffusion. One system was the Airtight Drywall Approach (ADA), and the other, the sealed polyethylene system.

The ADA system relies on the drywall and framing members to provide a continuous air barrier. This requires that all junctions between framing members and between the drywall and framing members be well sealed with gaskets and caulking. Paint is used to provide a vapour retarder. The sealed polyethylene system provides a combined air/vapour barrier with a continuous membrane of polyethylene sealed with caulking.

Builders have been refining air-sealing techniques in an attempt to simplify the installation of air and vapour retarders and to develop a system that would interfere as little as possible with the normal work of the other trades. As a result, "hybrid" systems have been developed which use features of both the ADA and the sealed polyethylene systems.

The objectives of this project were to:

1. evaluate current air-sealing and vapour barrier construction practices and to develop refined techniques;
2. incorporate refined ADA and polyethylene techniques into the construction of a two-dwelling research and demonstration residential building referred to as the Cold Climate Demonstration House;
3. compare and assess the different approaches to providing this air/vapour barrier.

This report documents the results of work carried out in accordance with these objectives.

In addition, the project involved the incorporation of a range of electronic monitoring equipment to assess not only the different sealing techniques but also to meet the monitoring requirements of a number of research projects planned for the future.

2.0 BUILDING SCIENCE ISSUES

Air leakage plays a major role in the performance of buildings and has been linked to a number of residential problems including high energy costs, moisture in ceilings and exterior walls and poor control over indoor humidity conditions. With the energy crisis of the 1970's, energy conservation became an important issue and reducing air leakage by sealing the building envelope was the major technique used to reduce high residential heating bills.

The comprehensive air-sealing techniques developed for low energy house construction became a significant factor in reducing wall and attic moisture problems. Unfortunately, modest air-sealing often increased the problem. Reduced natural airchange due to a tighter building envelope resulted in higher indoor humidity levels. Exfiltration of interior air with a higher moisture content was now concentrated at fewer leakage openings leading to localized moisture shock. In climates with insufficient drying potentials, moisture problems were not uncommon. To prevent wall and attic moisture problems, therefore, air-sealing of the building envelope must be comprehensive and indoor humidity levels must be controlled.

In addition, the tighter building envelope reduced the natural supply of house air required by combustion appliances. This contributed to unsafe operating conditions such as backdrafting and spillage. To prevent these problems, therefore, a well sealed home must have a properly designed combustion air venting system.

2.1 Fundamentals

If houses are to be protected from the damaging effects of moisture, mechanisms of moisture movement, air flow and pressure differentials must be understood.

The major ways that moisture penetrates the building envelope are air leakage and vapour diffusion. Although air leakage is far more damaging than vapour diffusion, it is not common practice to install a continuous air barrier. The need for the air barrier has been recognized somewhat, however, in the current use of the term air/vapour barrier to describe air-sealing systems in housing. The term is confusing since it implies that the performance criteria for an air barrier and a vapour retarder are the same, but this is not the case. The 1985 National Building Code clearly separates the function of each in Section 5.2: Control of Vapour Diffusion , and Section 5.3: Control of Air Leakage.

2.2 Air Leakage and Air Barriers

Air leakage is the major mechanism by which moisture and heat are transported through the building envelope. Air leakage occurs when there is a continuous path through the building envelope from the inside to the outside and when an air pressure difference exists across this opening. When air moves into the building envelope as a result of a positive pressure difference, moisture in the air will be transported with it. If the moisture comes in contact with a cold surface, or condensing plane, it will condense and accumulate. Air leakage can deposit hundreds of times more moisture than would be transported through vapour diffusion in the same time period. This moisture can lead to severe deterioration of the walls and ceiling over time.

The function of an air barrier is to stop outside air from infiltrating a building and to stop inside air from exfiltrating the building envelope to the outside. In order to be effective, air barrier materials and installation techniques must meet a number of requirements.

- The air barrier must be continuous. Air barrier material in the wall must be continuous with air barrier material in the ceiling, around windows and doors, through the rim joist, etc.

- The air barrier must be able to resist displacement due to pressure differences caused by wind, the stack effect within buildings and pressurization from the operation of combustion and ventilation equipment.

- The air barrier materials must be virtually impermeable to air flow. Air impermeable materials would include polyethylene, metal or glass, gypsum board and cast-in-place concrete.

- The air barrier should be made of materials known to have a long service life, or be positioned to allow for periodical servicing.

2.3 Vapour Diffusion and Vapour Retarders

Moisture in a vapour state diffuses through building materials at a rate determined by the permeability of the material and the vapour pressure difference across that material. The major function of a vapour retarder is to slow down, or retard, this moisture movement and, for this reason, is often referred to as a vapour diffusion retarder.

Vapour retarder materials offer a higher resistance to vapour diffusion than most other materials. Although polyethylene film is most commonly used for this purpose, materials such as aluminum foil, some paint products, metal, glass, and mastics may be suitable as vapour retarders.

A vapour retarder should not necessarily be expected to act as an air barrier since performance criteria for an air barrier are different and more demanding. The vapour retarder, for example, does not have to be continuous. Vapour diffusion is a function of surface area, and if the vapour diffusion retarder covers 90% of the building envelope surface area, then generally it is 90% effective. For this reason, unsealed joints and minor cuts in the retarder do not appreciably affect the overall performance of the vapour retarder. As has been seen, it is the continuity of the air barrier which is important.

2.4 Location of Air Barriers and Vapour Retarders

All exterior walls and the ceiling should have both a vapour retarder and an air barrier since each barrier performs a separate and distinct function. Air barriers and vapour retarders may, or may not, be the same component. A combined air/vapour barrier must meet the performance criteria of both barriers.

The vapour retarder should be placed to the warm side of the insulation in order to control condensation. If it is necessary or desirable to place it inside the insulation, it should be in no further than the point at which the temperature of the inside air drops to its dew point. The position of the air barrier is less critical, and it is not essential that it be placed to the warm side of the insulation. If it is positioned to the outside, however, the air barrier material should have a water vapour permeability sufficient to allow the passage of vapour moving to the outside.

2.5 Ventilation and Heating Systems

Conventional building envelopes rely upon infiltration and exfiltration through a random distribution of leakage openings to provide the natural ventilation required to maintain good indoor air quality and to dilute indoor moisture levels. As building envelope airtightness increases, however, the amount of natural airchange that the house experiences decreases, and there is a greater potential for problems such as condensation, backdrafting and spillage of combustion appliances and the concentration of indoor air pollutants.

Ventilation is the process of exchanging indoor and outdoor air. This may be natural ventilation, which occurs without the use of mechanical devices, or controlled ventilation, which refers to airchange created by electric fans. The 1985 Alberta Building Code requires that a house have a mechanical ventilation system capable of providing one-half an airchange per hour. The type of system is not specified, however, and could be an exhaust-only system or a supply and exhaust system with or without heat recovery.

Regardless of the type of system chosen, any ventilation strategy should satisfy a number of performance requirements.

- It should be capable of providing a continuous supply of fresh air to each habitable room of the house at a rate of about 10 cubic feet per minute (cfm). Additional air requirements of 50 cfm for bathrooms and 100 cfm for kitchens, supplied on an intermittent basis, are also required.

- It should be capable of being controlled and be equipped with a variable speed control to adjust the continuous flow rate and with a dehumidistat to provide additional ventilation as necessary to dilute indoor moisture levels.

- It should not affect the operation of any combustion appliance. A ventilation system that exhausts house air faster than it can be replaced will create a negative indoor pressure and the potential for backdrafting and spillage.

- It should meet minimum comfort requirements. Cold outside air must be tempered before being distributed throughout the house if drafts and cold spots are to be prevented.

Appliances that require combustion air such as furnaces, hot water heaters, fireplaces and wood stoves compete for indoor air with appliances that exhaust house air such as clothes dryers, exhaust fans and built-in vacuums. As houses become more airtight and natural infiltration is reduced, situations arise where an inadequate supply of house air can cause unsafe operating conditions such as backdrafting or spillage.

The ideal method of dealing with this issue is to uncouple all combustion equipment from the influence of indoor air pressures. This can be accomplished to varying degrees with technology that is now available. Although most induced-draft gas furnaces and water heaters still require combustion air, they have power fans to mechanically exhaust combustion products. As a result, they no longer draw the large volume of house air required by naturally aspirating appliances to maintain an effective chimney draft. These induced draft appliances can withstand negative indoor pressures in excess of 50 Pascals without any danger of spillage or backdrafting.

Sealed combustion gas furnaces and water heaters are also available. These units are completely uncoupled from the house and draw all their air requirements directly from outside. They completely eliminate the unsafe operating conditions associated with naturally aspirated appliances.

Fireplaces can be effectively uncoupled from the house by providing tight fitting glass doors and ensuring that a combustion and draft-control air duct is installed from the firebox to the outside.

3.0 AIR-SEALING APPROACHES IN CONSTRUCTION

3.1 Use of Polyethylene in Housing

Polyethylene film began to be widely used as a vapour retarder in residential construction in the early 1970's. As it became evident that air movement was a significant factor in moisture movement, the term air/vapour barrier was adopted and by the late 1970's polyethylene was being promoted as such. At this point, however, it was not being installed in a continuous manner and areas such as the rim joist, windows and doors and penetrations in the building envelope were typically ignored. This changed as a result of the energy crisis and by the early 1980's, the design and construction of extremely well-sealed homes was being encouraged. This trend was encouraged by a Federal energy-efficient housing initiative, the R-2000 Program, and today well-sealed homes are not uncommon.

Although polyethylene is widely used, the following concerns exist regarding its use as an air/vapour barrier.

- Significantly increased levels of workmanship are required to successfully install it.
- A polyethylene air/vapour barrier is hidden inside the building envelope and cannot be inspected for damage or be repaired.
- Polyethylene film is subject to durability problems such as ultra-violet and thermal degradation.
- Work carried out by the Division of Building Research of the National Research Council indicates that, as it is currently installed, polyethylene film is not adequately supported to resist the wind and stack air pressures which act on it. Under peak wind-loading conditions, for example, the polyethylene seal can be ruptured and the film sucked into the wall cavity compressing the insulation.

Inadequacies of polyethylene as an air barrier prompted researchers to develop an air-sealing system that eliminated the use of polyethylene and relied on the building's framing members and the use of gaskets, caulking and paint to provide an air barrier and vapour retarder. The system developed was the Airtight Drywall Approach (ADA).

3.2 Initial ADA Houses

The Airtight Drywall Approach was initially installed in stages with interior partition walls being constructed after exterior walls had been assembled and drywalled to form a tight seal. This required scheduling two trips for the carpenters, drywallers and electricians. A detailed discussion of initial experiences with the Airtight Drywall Approach in Ontario is presented in a feasibility study titled, *A New Approach to Affordable Low Energy House Construction* (ISBN 0-88654-074-7), published by the then Alberta Department of Housing in July, 1984.

Building on lessons learned from the Ontario experience, a modified approach was demonstrated in three houses constructed in Edmonton, Alberta during the summer of 1984 and is detailed in the Alberta Municipal Affairs publication, *Construction Experience Using the Airtight Drywall Approach* (ISBN 0-88654-116-6), March, 1985. The experience with these houses showed that trade scheduling, notching of gypsum board sheets around cast-in-place floor joists, gasket durability, cost and long term performance were problem areas that had to be dealt with. These concerns were addressed in two subsequent projects.

3.3 Recent Demonstration Projects

1) *ADA Demonstration Project by Flair Homes in Winnipeg.*

Preliminary results have indicated that commonly used polyethylene foam rope is not a suitable gasket. The air pockets within these materials rupture when subjected to significant loading and retain their compressed shape. This problem appears to be solved by using closed-cell neoprene and vinyl base glazing tapes and weather strips, or with EPDM base gasket materials. The long term durability of these materials has been proven in the glazing, weatherstripping and automotive industries and is expected in ADA applications. Notching of the drywall was eliminated in this project and replaced with continuous gasketing. Details are presented in *Construction Experience Using the Airtight Drywall Approach.*

2) *Bonneville Power Administration ADA Demonstration Project.*

Oregon and Idaho addressed the problem of trade scheduling. The solution involved constructing interior partition walls with a single top plate to allow the

ceiling gypsum board to be slipped over the top. This modification allowed for the framing, drywalling, electrical, plumbing and mechanical trades to be scheduled as in conventional house construction. Significant labour savings occurred since large sheets of drywall could be utilized effectively on exterior ceilings. The only concern was that the builder now had to rely on the drywall installers to insure that interior partition walls were perpendicular prior to fastening them to the underside of ceiling framing. The procedure is also detailed in *Construction Experience Using the Airtight Drywall Approach*.

4.0 EVALUATION OF CURRENT AIR-SEALING TECHNIQUES

Builders have been refining air-sealing techniques in an attempt to simplify their installation and to develop a system that will interfere as little as possible with the normal work of the other trades. They have developed "hybrid" systems which use components of both the ADA and the sealed polyethylene methods. Air-sealing systems are evolving that can be installed in one trip, immediately prior to drywall application.

4.1 Air-Sealing Materials

A wide variety of air-sealing products are currently being used and builders are continually experimenting with new ones. The need is for products that are durable, inexpensive, easy to install and capable of being installed in cold weather.

4.1.1 Gaskets

Open cell gaskets such as polyethylene backer rod, closed cell gaskets such as neoprene and synthetic rubbers such as EPDM are being used in a variety of air-sealing applications.

The open cell gaskets are most widely used because of their availability and low cost. Their major disadvantage, however, is that they lose their resilient characteristics under heavy loading and remain compressed. As a result, their use as an air seal under exterior walls, for example, is questionable and, therefore, not recommended.

A product that solves this problem is a saturated foam sealant tape. It is an open cell, elastomeric foam impregnated with a non-bituminous sealing material and coated with pressure sensitive adhesive. The product is in the form of an adhesive backed foam strip which compresses easily, recovers rapidly and has a maximum compression set of only 10%. It is available in a variety of widths and thicknesses. Although relatively inexpensive, this product is currently available only through suppliers in the United States.

4.1.2 Films and Membranes

The following films and membranes are being used in air-sealing applications.

- *Polyethylene film* is used as the air barrier in the sealed polyethylene system because it is light, relatively tough, inexpensive, manufactured in usable sizes and fairly easily installed. Although widely used, polyethylene is not recommended as an air barrier because of the concerns outlined in Section 3.1.

- *"Tyvek"* is a sheet of high-density polyethylene fibres manufactured by Dupont. It is tougher than polyethylene film and, therefore, not as easily damaged. Tyvek is relatively impermeable to air and bulk water and is used as an exterior weather barrier in residential construction to replace building paper.

  Unlike polyethylene, Tyvek is permeable to water vapour and will not function as a vapour diffusion retarder. It can, therefore, be placed on the cold side of the building envelope. As a result, some builders are using it to replace polyethylene as the air barrier around the rim joist.

- *"Perm-A-Barrier"* is a membrane composed of a cross laminated polyethylene together with a thick layer of rubberized asphalt and manufactured by W.R. Grace Ltd. It is a self-adhering membrane about 1/32 inch thick that is impermeable to both air and moisture. Although developed for commercial use, Perm-A-Barrier is being used in residential construction to seal the rim joist.

4.1.3 Caulking

Caulking is used to seal two surfaces that meet but do not move such as duct outlets or overlapping layers of polyethylene. If the joint does move, the seal will quickly fail. Caulking is best applied inside the building enclosure to prevent moisture from accumulating in wall and ceiling cavities. It should be chosen for its ability to adhere and remain flexible over a long period of time. A wide variety of products are available and their use depends on a number of factors including ease of application under field conditions, cleanup, whether the sealant will be exposed or covered and whether a high degree of flexibility is required.

Characteristics of available caulkings are given below.

- o *Oil or resin base caulkings* are low cost but durable for only one or two years and form a hard surface when dry.

- o *Latex base and butyl rubber caulkings* are durable for 5 to 20 years but are only useful for small-movement joints. Latex base caulkings should not be used in constant-moisture environments since they are susceptible to mildew.

- o *Silicone caulking* is durable for more that 20 years, can be used for large-movement joints and has high moisture resistance, but is expensive, requires special cleaners and is difficult to apply in cold weather.

- o *Acoustical sealant* is durable for more than 20 years and is low cost but is non-hardening (must be covered), is messy to use and should not be used on the exterior. This product is excellent for joining polyethylene.

4.1.4 Foams

Polyurethane foams are available in aerosol cans and are being used to seal penetrations in the building envelope and to seal around windows and doors. Both expanding and non-expanding foams are available. Expanding foams are especially useful to seal large gaps but require care when being applied since some expand as much as 2 1/2 times. Non-expanding foams are available from commercial suppliers and will be easier to use for most residential air-sealing applications.

4.2 Vapour Retarder Materials

The Alberta Building Code requires that all insulation be protected by a Type 2 vapour retarder (one having a vapour diffusion rating of less than 60). This means that no more than 60 nanograms of moisture can pass through one square metre of the material per second when the difference in water pressure is one pascal. This requirement is satisfied in the sealed polyethylene system with polyethylene.

The ADA system proposes that polyethylene be eliminated and paint combinations conforming to Type 2 vapour retarder requirements be used as the vapour retarder. Work has been carried out for Alberta Municipal Affairs by the Alberta Research Council (ARC) on the feasibility of this approach. ARC testing revealed that combinations of latex emulsion

sealer and latex paint did not provide adequate vapour retarder protection. Examples of paint combinations that have a vapour diffusion rating of less than 60 are given below:

- o 1 coat alkyd base sealer + 1 coat latex emulsion paint;
- o 1 coat latex emulsion sealer + 1 coat alkyd base enamel;
- o 1 coat vapour retarder paint + 1 coat latex emulsion paint.

The main finding was that any paint combination of oil base (alkyd) paint or vapour retarder paint on drywall results in vapour diffusion ratings of well under 60.

4.3 Current Air-Sealing Practices

Current methods for sealing the building envelope are detailed below.

4.3.1 Rim Joist - Main Floor and Second Storey

Techniques for sealing the rim joist have undergone the greatest number of refinements. Air barriers created by wrapping the rim joist with polyethylene, or by installing gaskets between each of the framing members through this area, have been replaced by air barriers formed by installing blocks of wood or rigid polyurethane between the floor joist and caulking them where they fit against the joist and subfloor.

If floor joists are cast in place, builders install a rim joist that is one size larger than the floor joist. This technique reduces air leakage at the bottom of the rim joist because of the resulting longer and more indirect air leakage route. Builders using this techniques no longer notch and seal the interior drywall between the floor joists.

The most recent innovation is the use of membranes on the exterior to seal this area. This method is discussed in greater detail later in the report.

4.3.2 Building Envelope Penetrations

Penetrations through the air barrier to the exterior are typically being sealed with a rubber gasket. The rubber is the same material used by a plumber to seal around shower drains and is similar to inner tube rubber. Any pipe, conduit or duct passing to the exterior is fitted

with this gasket material. A hole is cut in the gasket that has a diameter smaller than that of the pipe, conduit or duct to ensure a tight seal. The gasket is then caulked and nailed to the framing member that has been penetrated.

Spray applied foams are also being experimented with to seal these areas. All penetrations can be sealed quickly and easily once the various trades have finished their work. In this way, the builder does not have to rely on the work of a number of different subtrades to ensure a good air seal.

4.3.3 Walls and Ceiling

The walls are generally air sealed using one of two basic methods.

1) Gaskets are installed along the top and bottom plates of the exterior wall prior to installing the drywall. A polyethylene backer rod gasket is most commonly used because of its low cost. The thickness of the backer rod is the most common complaint with this method since it causes the drywall to bow out somewhat at the plate.

   Interior walls are being framed in a conventional manner and are no longer being set away from the exterior walls and ceiling to allow drywall to be passed behind them. Gaskets are installed along the corner stud and top plate of interior walls to seal the junction between the interior and exterior wall and between the interior wall and ceiling.

   With this technique, the drywall acts as the air barrier but not as a vapour diffusion retarder. The Type 2 vapour retarder requirement is satisfied by using polyethylene or a paint combination having a perm rating of less than 60. Code requirements and cost dictate what builders use in different areas.

2) Polyethylene and caulking are installed to provide the air barrier which also serves as a vapour diffusion retarder. Six mil polyethylene and acoustical sealant are most commonly used. During construction, the major disadvantage with this method is that it is difficult to ensure that the subtrades will not damage this barrier which, once the drywall is installed, can no longer be inspected and repaired.

4.3.4 Electrical Outlets

Builders use a variety of methods to seal electrical boxes including flexible and rigid poly-hats with and without backing, caulked or gasketed wooden boxes, spray applied foam insulation, plastic electrical boxes, surface mounted electrical boxes and gaskets under the cover plates. No one method is commonly being used and a simple and effective method for sealing this area is still being sought.

4.3.5 Windows

Many techniques are being used to seal around windows. Some builders wrap the windows with polyethylene while others use a plywood wrap. In cases where the windows are installed as delivered, the air seal is achieved with a drywall return caulked to the window, gaskets or foam to seal the space between the window jamb and rough opening and even wide packing or duct tape to bridge the rough opening gap. Methods that are both simple and effective are still being sought.

4.4 Incremental Costs

The total incremental cost of air-sealing a house is made up of incremental time costs and incremental material costs. While material costs can be readily estimated, extra labour costs can vary significantly depending upon the complexity of the design, the method of application, and the experience of the installers.

The design of a house is a major factor in determining incremental time costs. If the detailing is simple, either the sealed polyethylene or the ADA system can be used, and it becomes relatively easy to reduce air leakage to R-2000 standards of 1.5 air changes per hour at 50 Pascals. As the design of the house becomes more complicated, however, and includes cantilevers, bay and bow windows, rooms over a garage, split levels, etc., overhead costs increase as draftsmen, supervisors and management become involved in determining how to continuously air seal a particular detail. Increased on-site supervision is also required to ensure that complicated detailing is constructed correctly. Otherwise, the cost of retrofit work for air-sealing that does not meet a specified standard could be expensive.

The tradespeople doing the work can also affect the cost of air-sealing significantly. Inexperienced trades require training and extra supervision which adds to

overhead costs. In addition, the price quoted by an inexperienced subtrade for a particular task involving air-sealing is usually high because they often do not understand what is involved.

Builders experienced with air-sealing techniques who construct the same type of house over and over, feel that incremental costs are no longer an important issue. The cost of air-sealing a basic 1200 ft2 house with experienced trades should cost no more than $300 using either the ADA system or the sealed polyethylene system. Builders also agree, however, that the use of complicated house designs and inexperienced tradespeople can result in incremental costs 3 to 4 times this amount.

Although the incremental cost of providing high levels of airtightness in new housing are low, the related costs of providing a controlled ventilation system and combustion appliances uncoupled from the effects of indoor air pressures are significant. The installed cost of a ventilation system with heat recovery can run as high as $1500. A medium-efficiency, induced draft gas furnace costs $500 more than a standard, naturally aspirated unit while the high-efficiency units cost $1500 more. The incremental cost of an induced draft or sealed combustion water heater cost about $600. These costs have fallen significantly over the last 5 years, however, and this trend should continue as new products are introduced and competition increases.

5.0 COLD CLIMATE DEMONSTRATION HOUSE

To compare and assess the effectiveness and practical use of recent air-sealing techniques, a number of techniques were incorporated into the Cold Climate Demonstration House (CCDH), a bilevel duplex designed, built and operated as a research and demonstration facility by Howell Mayhew Engineering Inc. An elevation of this building is shown in Figure 1 on page 18 with the floor plans presented in Figures 2 and 3 on pages 19 and 20, respectively.

The CCDH is a fully monitored research and demonstration facility which has incorporated several different building and mechanical systems used in low energy housing. These systems are being evaluated in an effort to simplify the construction process for the building trades and the operation and maintenance of the house for the occupants. The duplex was designed to the R-2000 standards of Energy, Mines and Resources Canada. A detailed description of the building is included in Appendix A.

The air-sealing techniques used on the CCDH were designed to:

a) simplify the installation of a continuous air barrier and a vapour diffusion retarder;
b) be used with conventional framing practices; and
c) interfere as little as possible with the scheduling and work of other trades.

ADA techniques were used on one of the duplex units while modified sealed polyethylene techniques were used on the other unit.

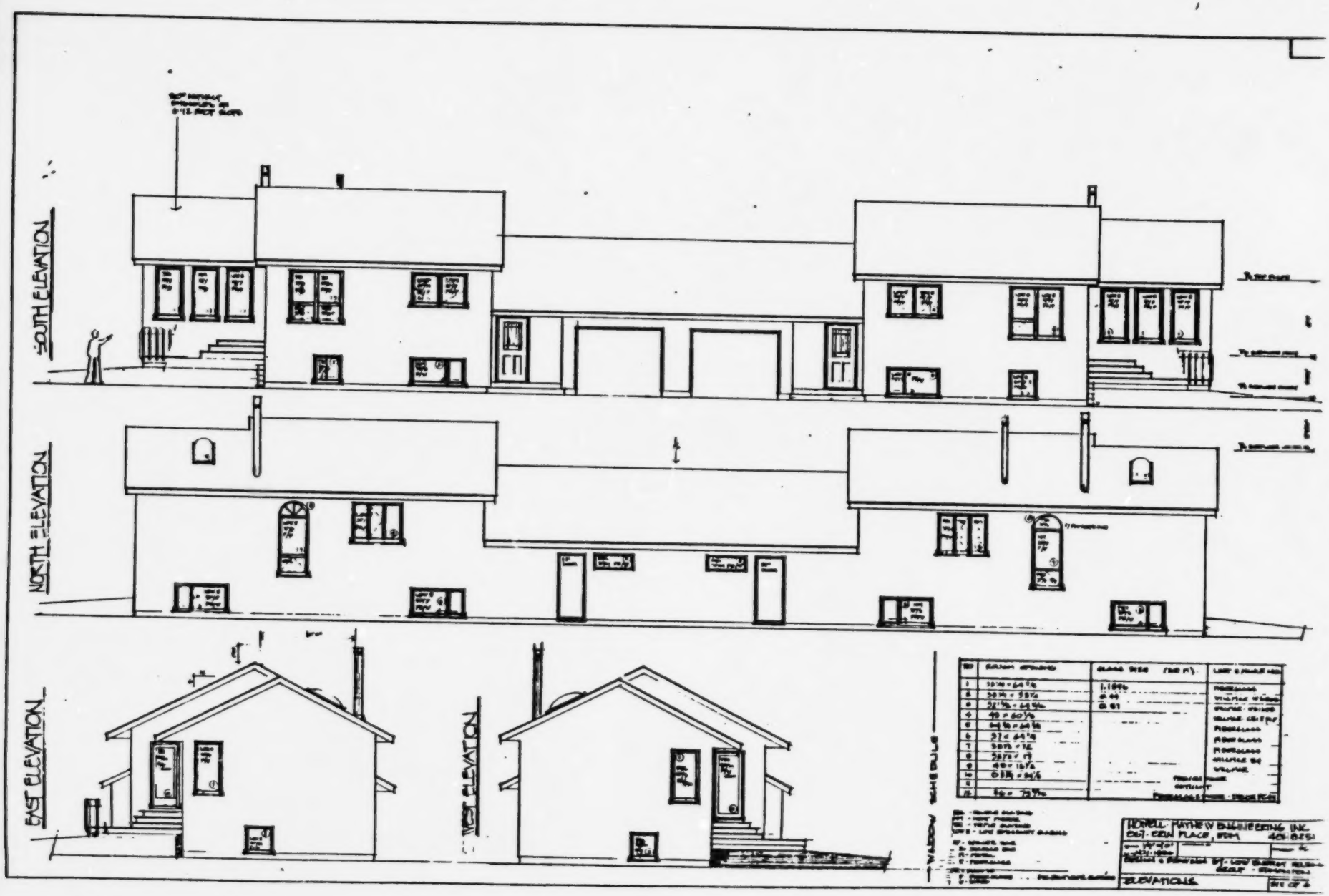


Figure 1: Elevations of CCDH

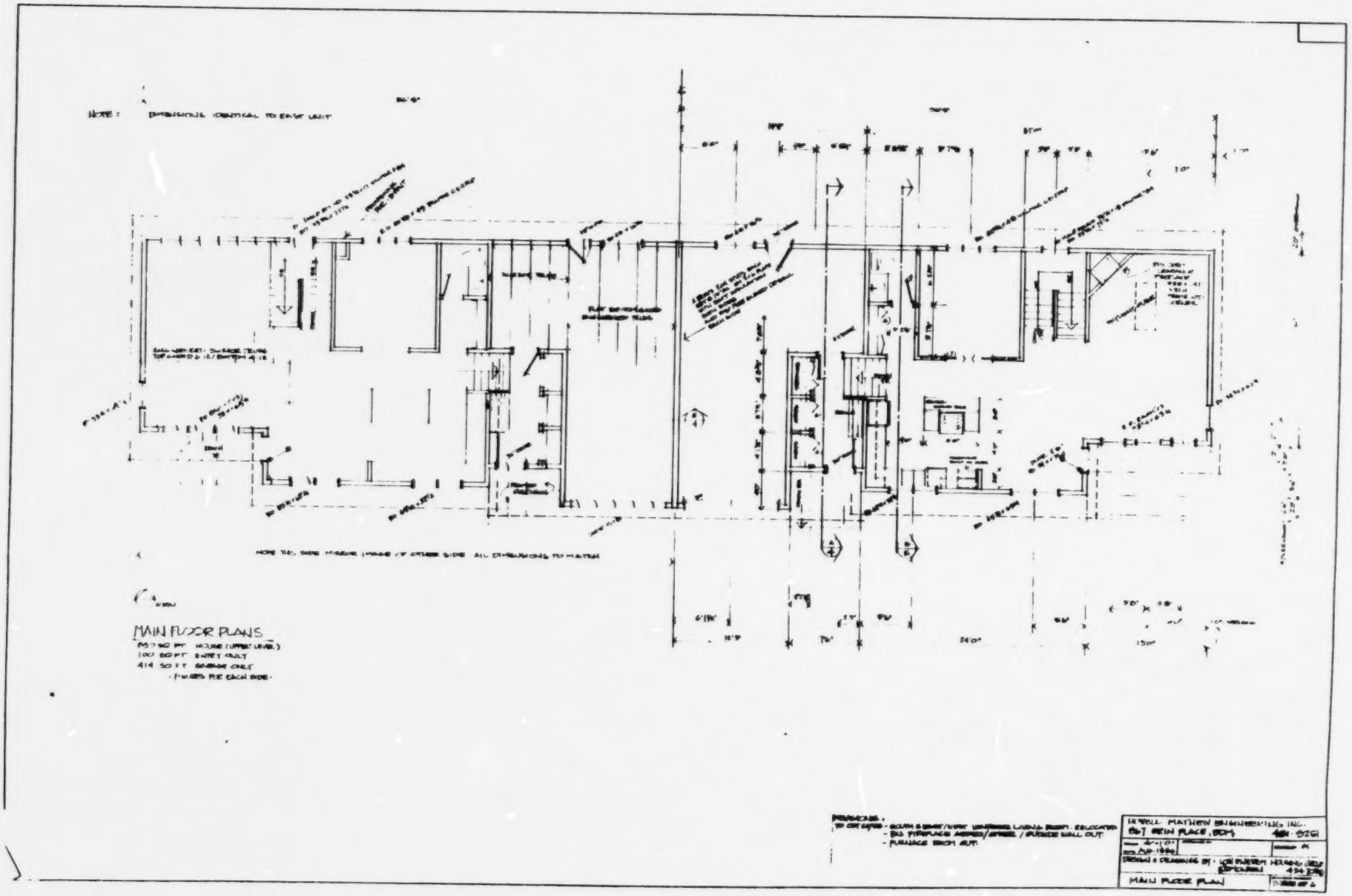


Figure 2: Main Floor of CCDH

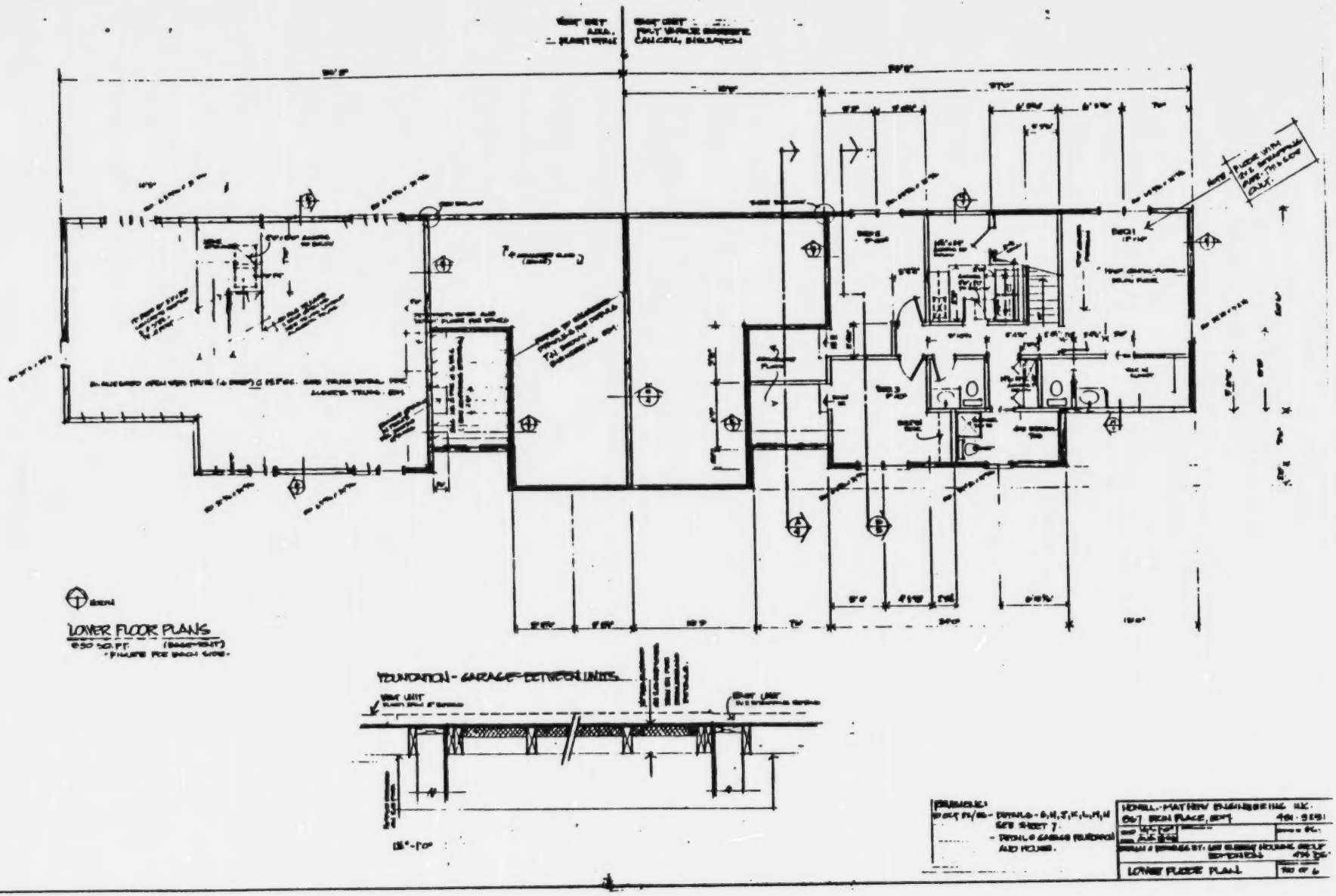


Figure 3: Lower Floor of CCDH

5.1 Air-Sealing Techniques

The following air-sealing techniques were used on the Cold Climate Demonstration House.

5.1.1 Rim Joist

Framing members through the rim joist (including plate material) were recessed in order that this area could be sealed and insulated in one step after the framing had been completed.

Three air barrier techniques were evaluated:
a) gasket plus rigid insulation;
b) gasket plus plywood; and
c) a bituthene membrane.

a) *Gasket plus rigid insulation (Figure 4 on page 22)*

With this method, the rigid insulation acts as the air barrier and the continuous seal is formed with a gasket. The exterior sheathing and/or the exterior finish provide the pressure required to make the seal continuous. This method was applied to the rim joist of the west unit of the duplex on the wall common with the garage.

Installation Procedure:

Vertical joints formed where two plates butt together were sealed with caulking or a piece of gasket prior to running the gasket along the length of the top and bottom plate. Rigid insulation was then installed directly against the gasket and tacked in place. A gasket was also installed at the butt ends of the rigid insulation. Since this area was inside the garage, drywall was the exterior finish that held the rigid insulation tight against the gasket.

Comments:

- Easiest system to install.
- Rigid insulation must be air impermeable since it also acts as the air barrier.
- Care is required to ensure joints between plates and between rigid insulation pieces are properly sealed.
- Adhesive backed gasket was applied at -10 C without any problems.
- Material cost of gasket and insulation was about $0.85 per lineal foot.
- One person could install about 50 lineal feet per hour.

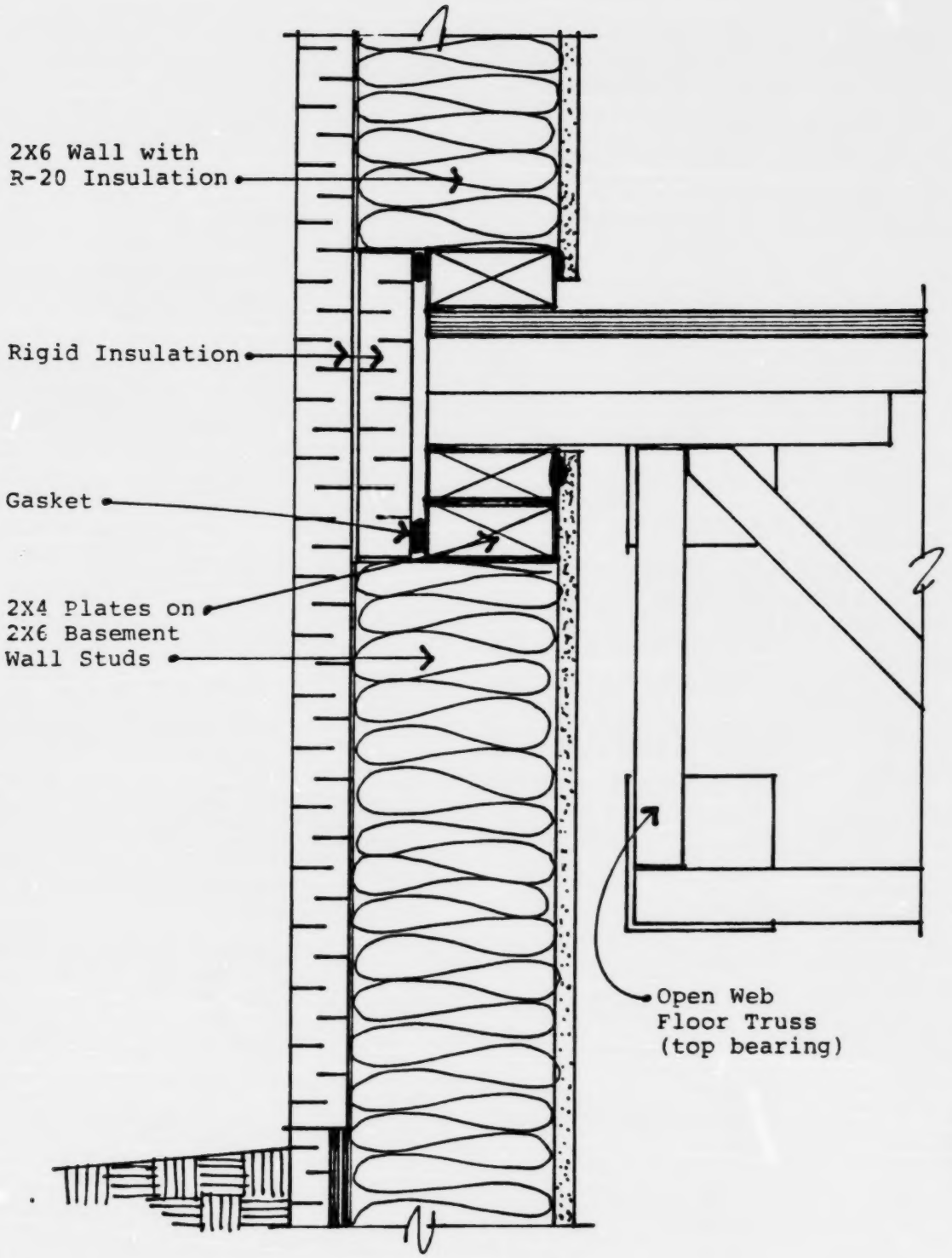


Figure 4 : Rim Joist - Gasket and Rigid Insulation

b) *Gasket plus plywood (Figure 5 on page 25)*

Plywood was installed over the gasket prior to installing rigid beadboard insulation. The plywood acts as the air barrier and the continuous seal was created using gaskets. This method was applied to the rim joist of the north and south walls of the west unit.

Installation Procedure:

Joints between plates were sealed with caulking or a piece of gasket prior to running a gasket along the length of the top and bottom plates. Plywood strips were then nailed directly against the gasket. A gasket was also installed at the butt ends of the plywood. Finally, rigid installation was pressure fit into the joist space next to the plywood.

Comments:

- o More labour intensive than previous method since both plywood and rigid insulation strips must be cut.
- o Care is required to ensure that the joint between plates and between pieces of plywood are properly sealed.
- o More flexibility with insulation type used since it does not have to act as an air barrier.
- o Can be used in situations where rim joist not recessed.
- o Adhesive backed gasket applied at -10 C without any problems.
- o Material for cost of gasket, plywood and insulation was about $0.80 per lineal foot.
- o One person could install about 40 lineal feet per hour.

c) *Bituthene Membrane (Figure 6 on page 26)*

This system eliminates the need for gaskets since the membrane forms the continuous air barrier. It was applied to the entire rim joist of the east unit and to the west wall of the west side of the duplex.

Installation Procedure:

Bituthene Primer P3100 was applied to the rim joist with a roller and allowed to dry to a tacky surface (about 30 minutes). The Bituthene Perm-A-Barrier membrane was then installed over the entire length and width of the rim joist and firmly rolled immediately to ensure good adhesion. Finally, rigid styrofoam was pressure fit into the rim joist over the membrane.

Comments:

- Rim joist must be recessed so that the membrane, which also acts as a vapour retarder, can be insulated to the outside and, therefore, kept to the warm side of the building.
- Easily applied but requires 2 people to handle wide membrane strip.
- Although specified for application in temperatures above 5 C, it was applied at -5 C without any apparent problems.
- Do not have to rely on installer to ensure that joints between plates and between pieces of plywood or rigid insulation are properly sealed.
- More flexibility with insulation type since joints between adjacent pieces do not have to be sealed.
- Must be cut to proper width since only available commercially in 3 foot wide rolls.
- Material cost of primer, membrane, and insulation was about $1.20 per lineal foot
- One person could install about 50 lineal feet per hour.

Alternate Installation Procedure:

In more conventional construction, strips of bituthene membrane about 4 to 5 inches wide can be used at the top and bottom of the rim joist to seal the cracks between the plate, subfloor and rim joist (Figure 7 and 8 on pages 27 and 28). This method can be used with exterior insulated sheathing as shown in Figure 7 or with plywood sheathing as shown in Figure 8. This will reduce the cost of using this membrane. Fiberglass batt insulation is then installed to the inside.

Comments:

- Easily installed by one person.
- The rim joist does not have to be recessed and insulated from the outside since the impermeable vapour retarder membrane only partially covers this area. This is an advantage to framers who use the rim joist to assist them in aligning walls.
- Material cost for primer, membrane, and insulation is about $0.75 per lineal foot.
- One person could install about 50 lineal feet per hour.

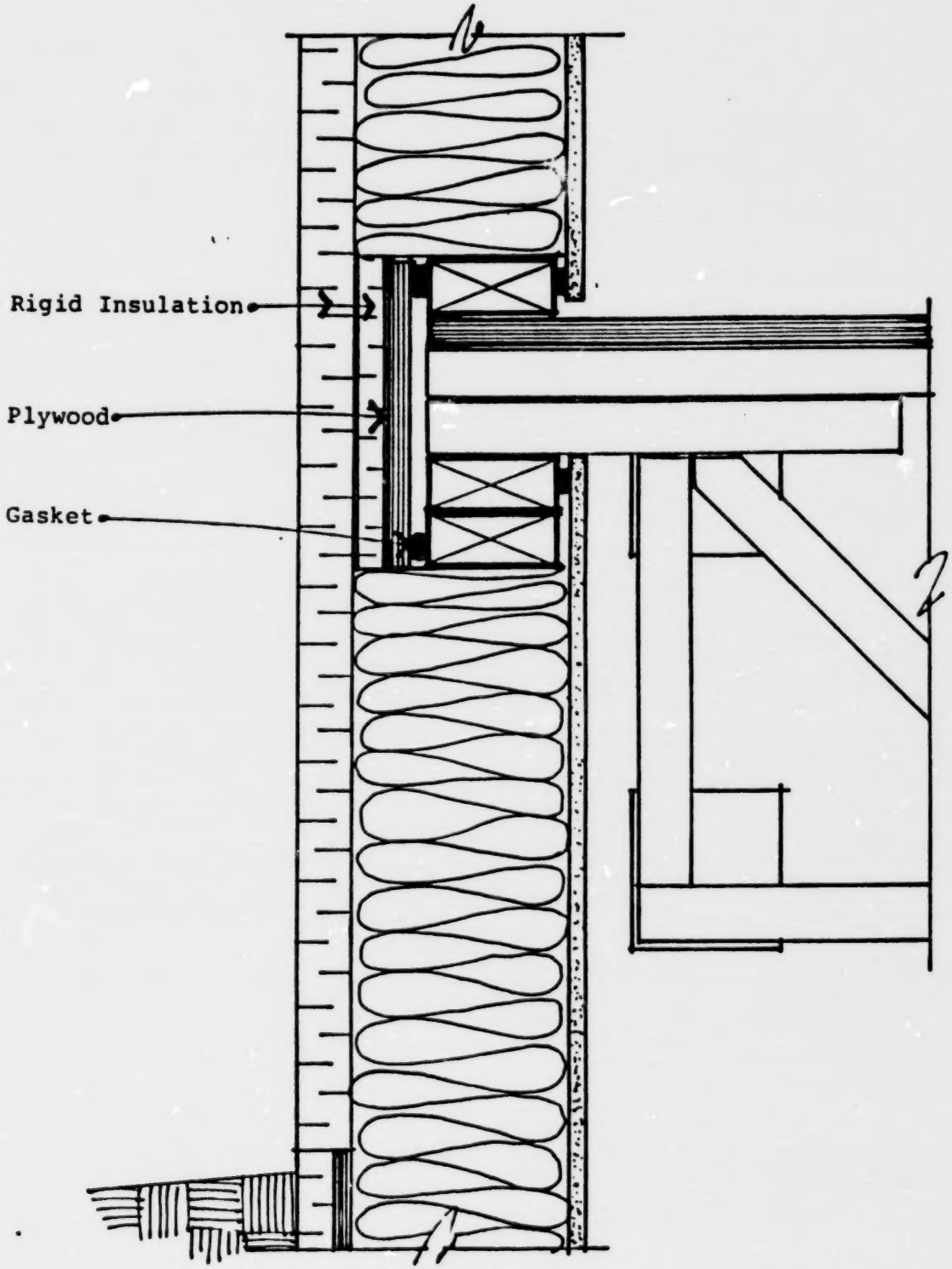


Figure 5 : Rim Joist - Gasket and Plywood and Beadboard

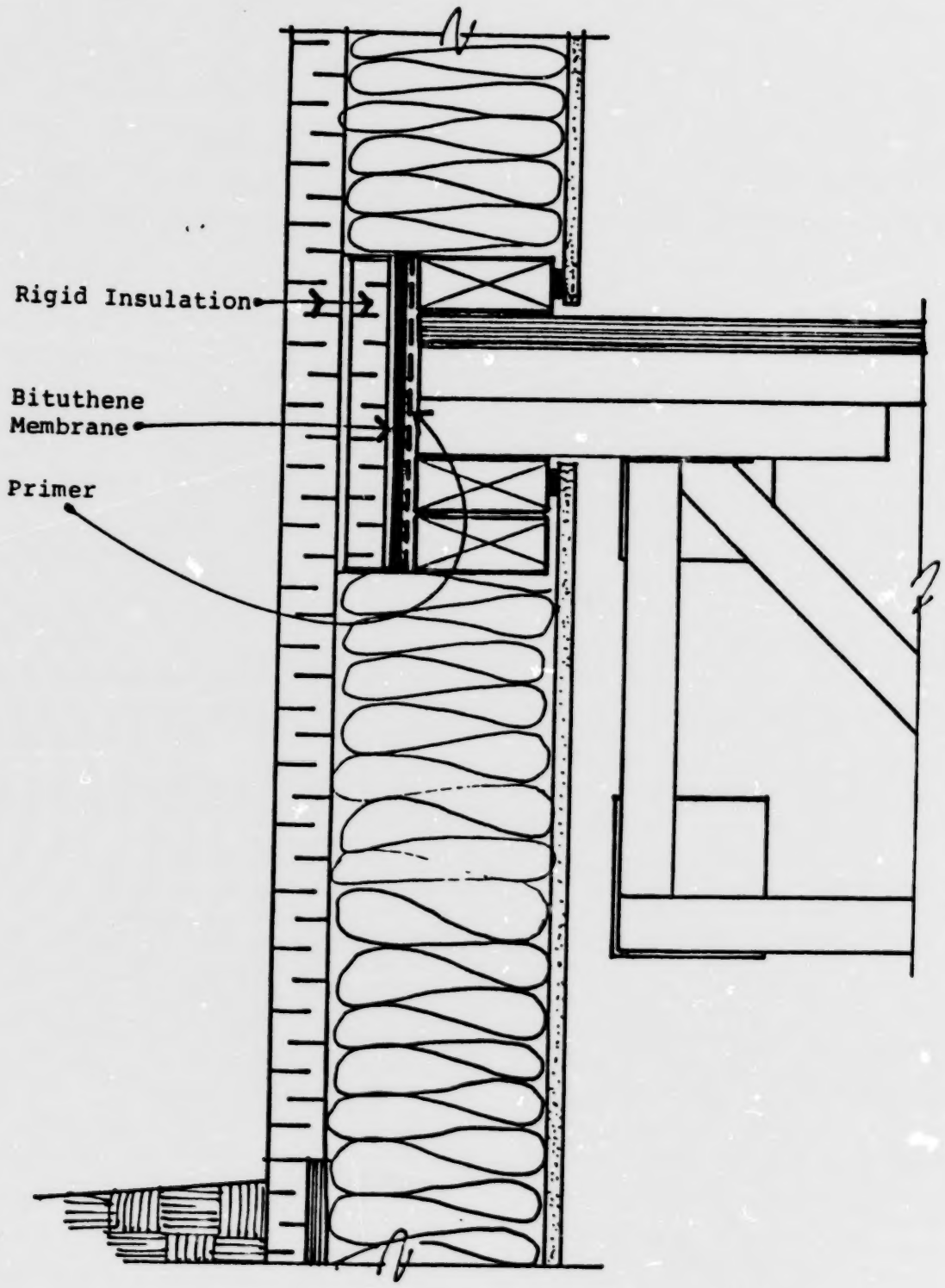


Figure 6 : Rim Joist - Bituthene Membrane

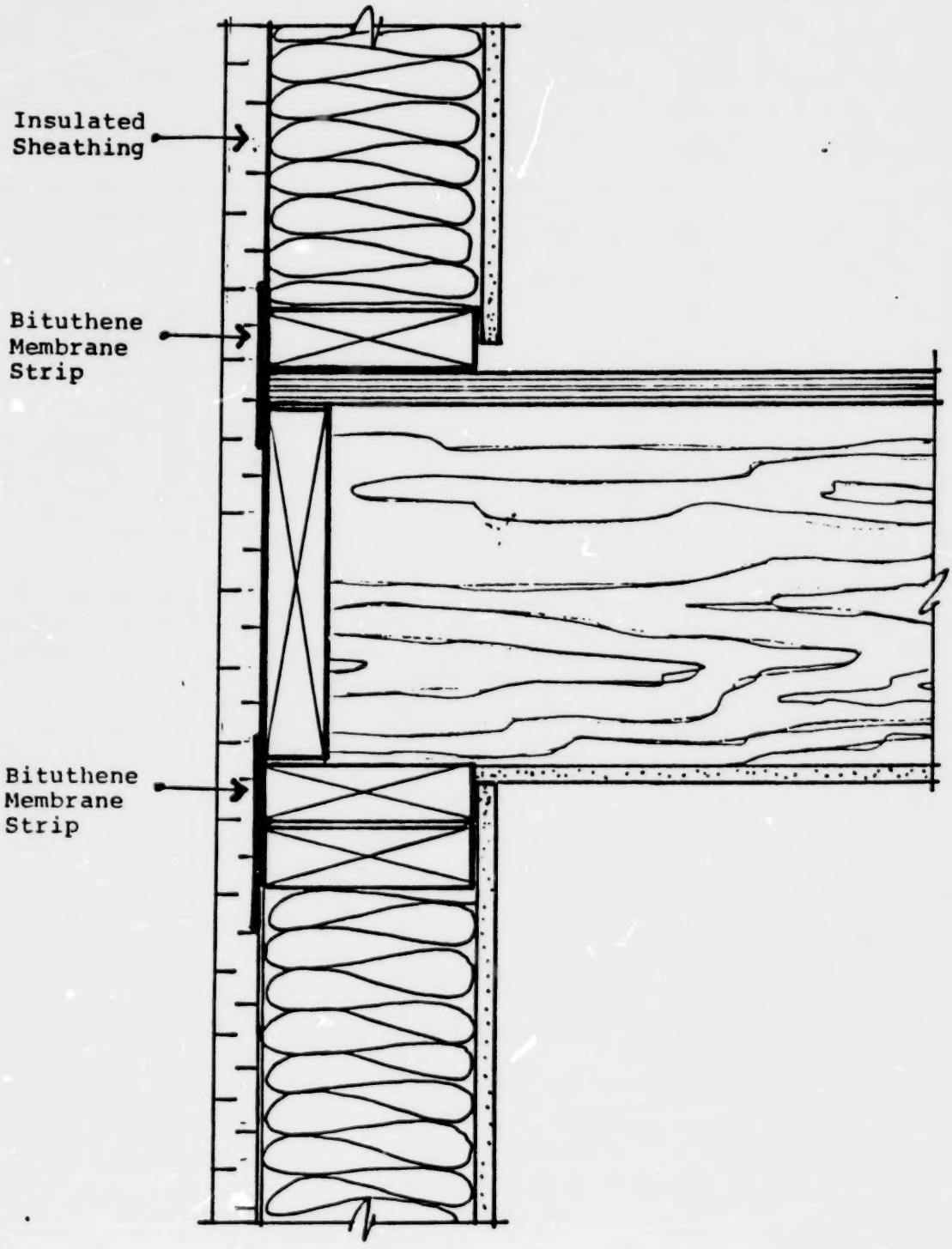


Figure 7 : Alternate Membrane Application:
Wood Foundation and Second Storey

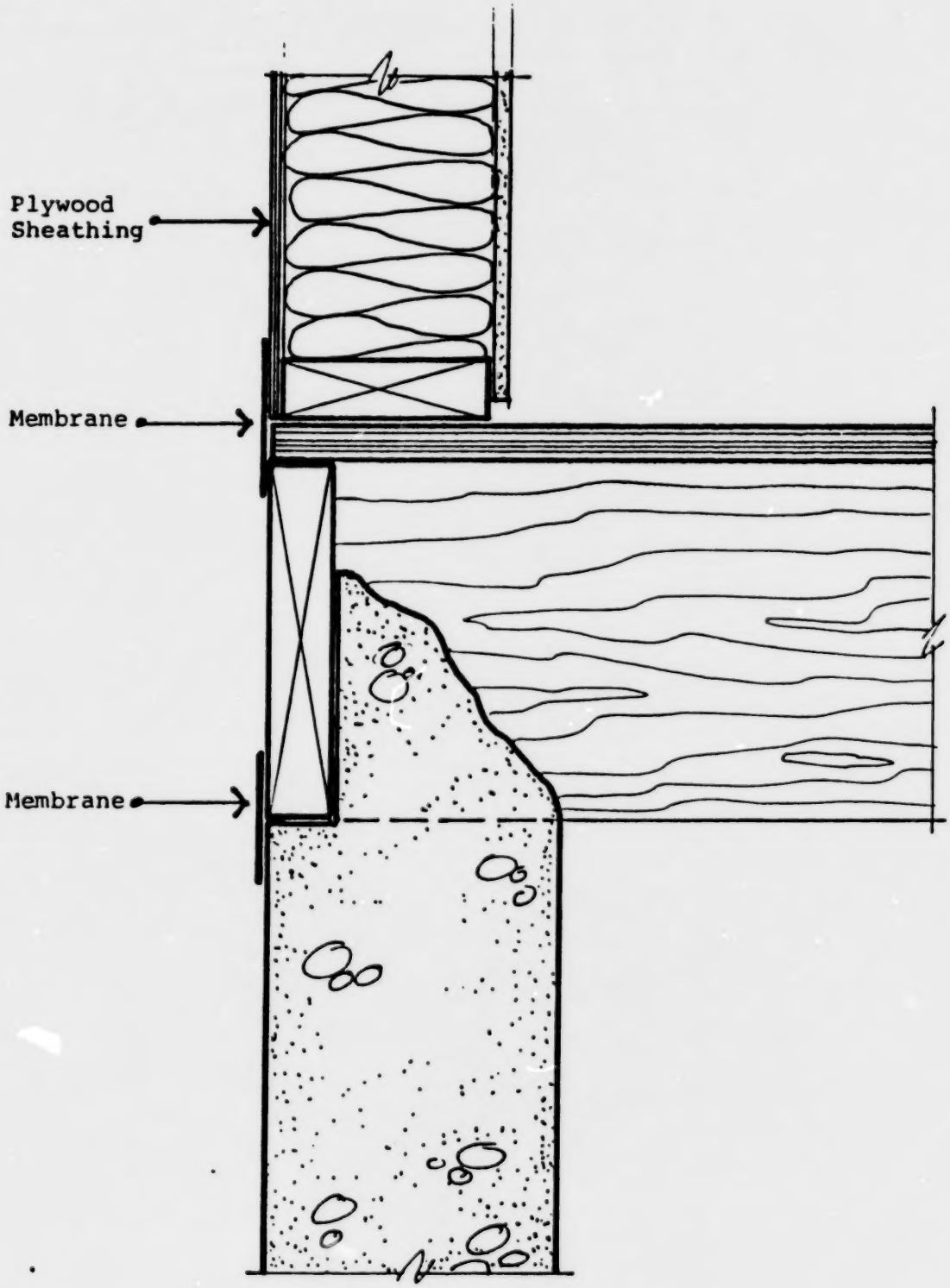


Figure 8 : Alternate Membrane Application - Concrete Foundation

5.1.2 Building Envelope Penetrations

Four different techniques were used to seal the various penetrations through the building envelope. The plumbing stacks were sealed with polyethylene and caulking (Figure 9 on page 30). The ducts for the heat recovery ventilator, the forced air system and the dryer were sealed using a rubber gasket (Figure 10 on page 31), and penetrations such as for the telephone and television cables, the monitoring conduits and the two pound gas line were sealed with spray applied polyurethane foam (Figure 11 on page 32). The furnace flue was sealed with a metal sleeve and heat resistant caulking (Figure 12 on page 33).

The rubber gasketing and the foam were found to be the superior techniques. The heating contractor was supplied with the rubber gasket and installed it at no extra charge. This method is also recommended for any plumbing penetrations. The foam was advantageous because it could be applied at anytime without interfering with the work of the other trades or having to rely on them to seal their own penetrations. Part of a $12 can of foam and 1/2 hour labour was all that was required to seal other penetrations through the building envelope.

5.1.3 Walls and Ceiling

Interior walls were framed in a conventional manner except on the main floor of the occupied side. These walls were framed after the polyethylene air/vapour barrier had been installed on the exterior walls.

On the side using the ADA system, saturated foam sealant gaskets were installed along the top and bottom plates of exterior walls and along the backing stud and the ceiling plate of interior walls (Figure 13 on page 34). Gasket sizes experimented with included 3/8 inch, 1/2 inch and 3/4 inch widths capable of expanding to a thickness of 3/8 inch. This thickness caused some difficulty for the drywallers since, over the length of the drywall, the gasket was not easily compressed. For future applications, a gasket size of 1/2 inch wide by 1/4 inch thick is recommended.

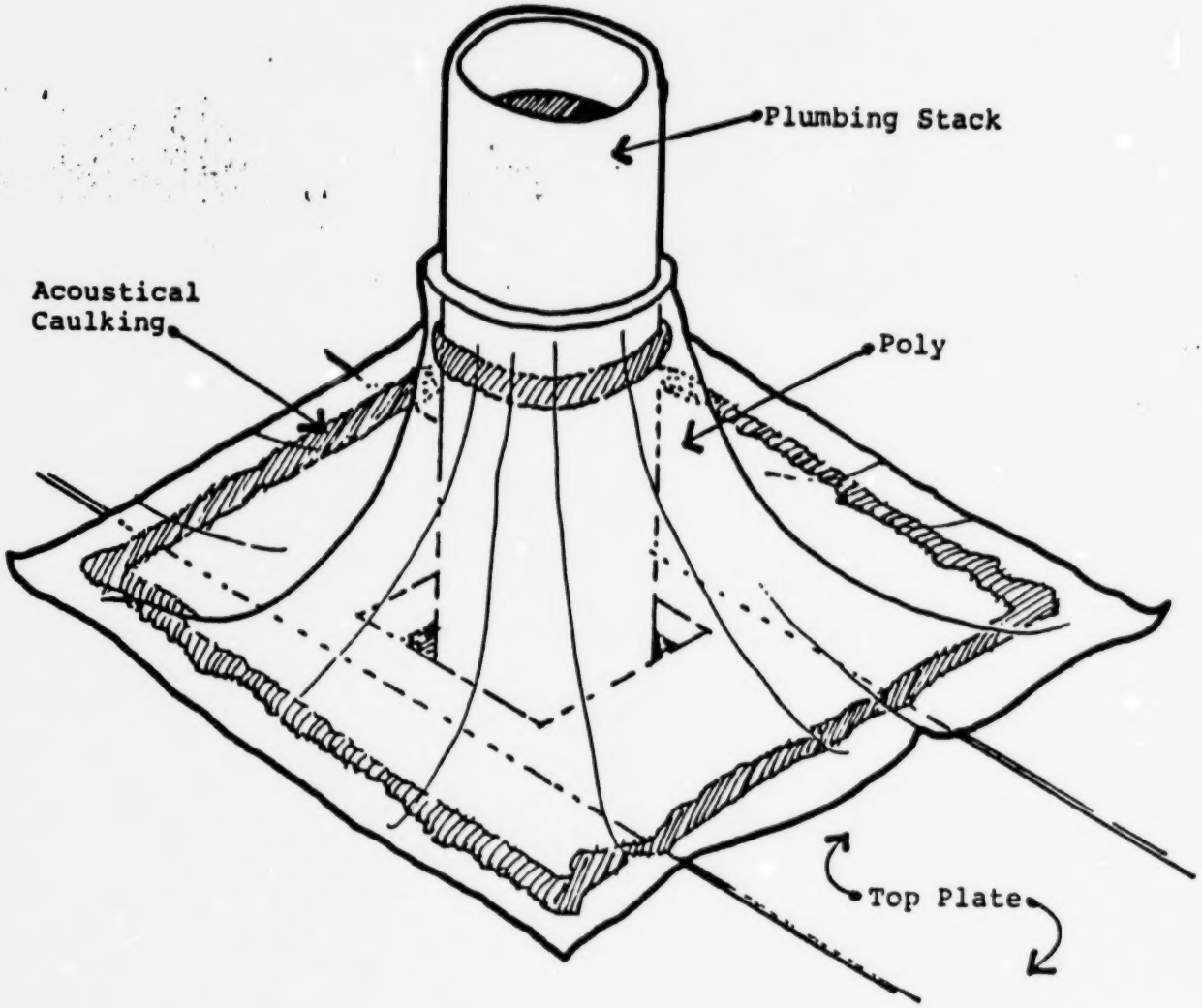


Figure 9 : Plumbing Stack Sealed with Polyethylene

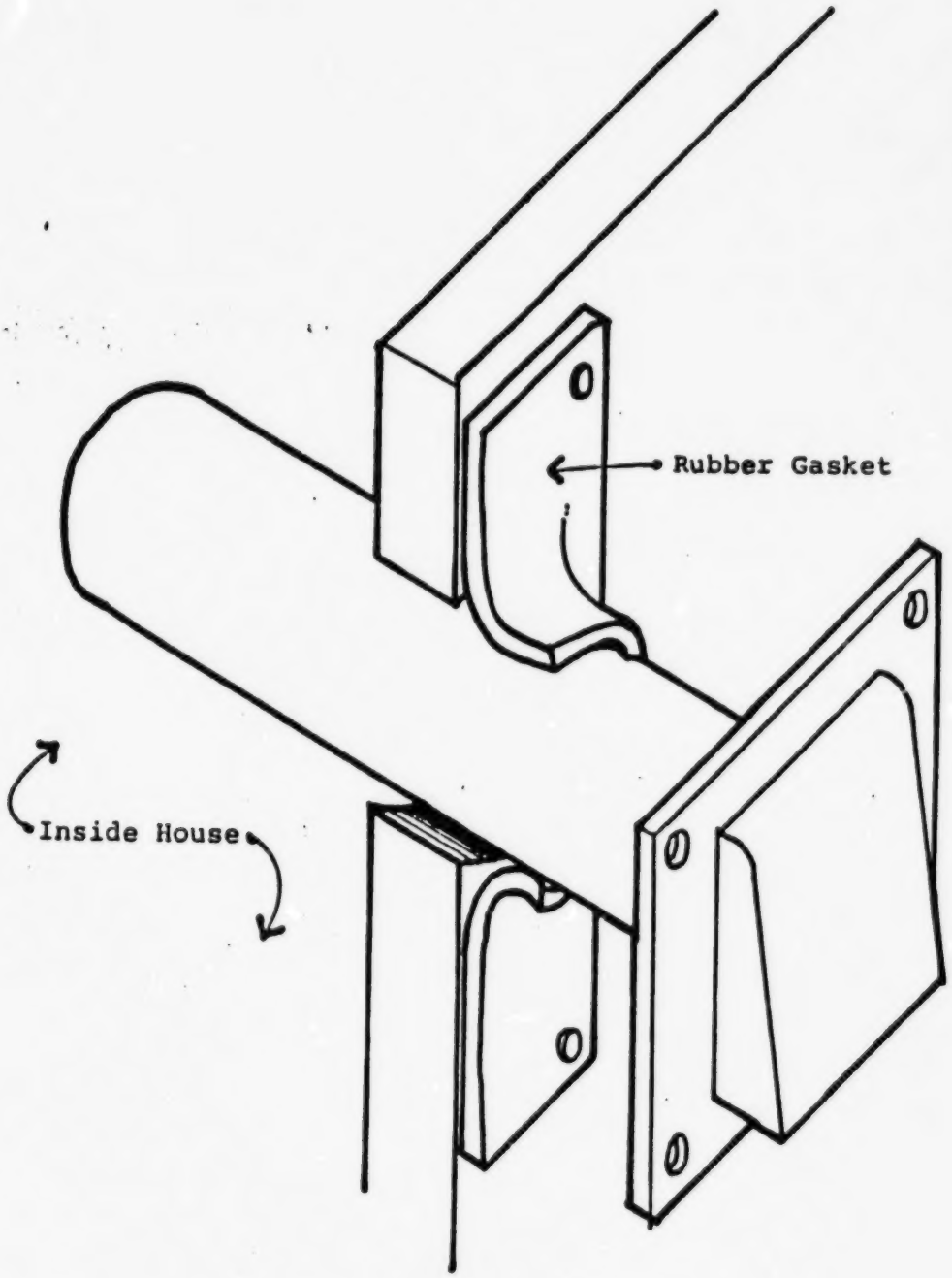


Figure 10 : Mechanical Duct Sealed with Rubber Gasket

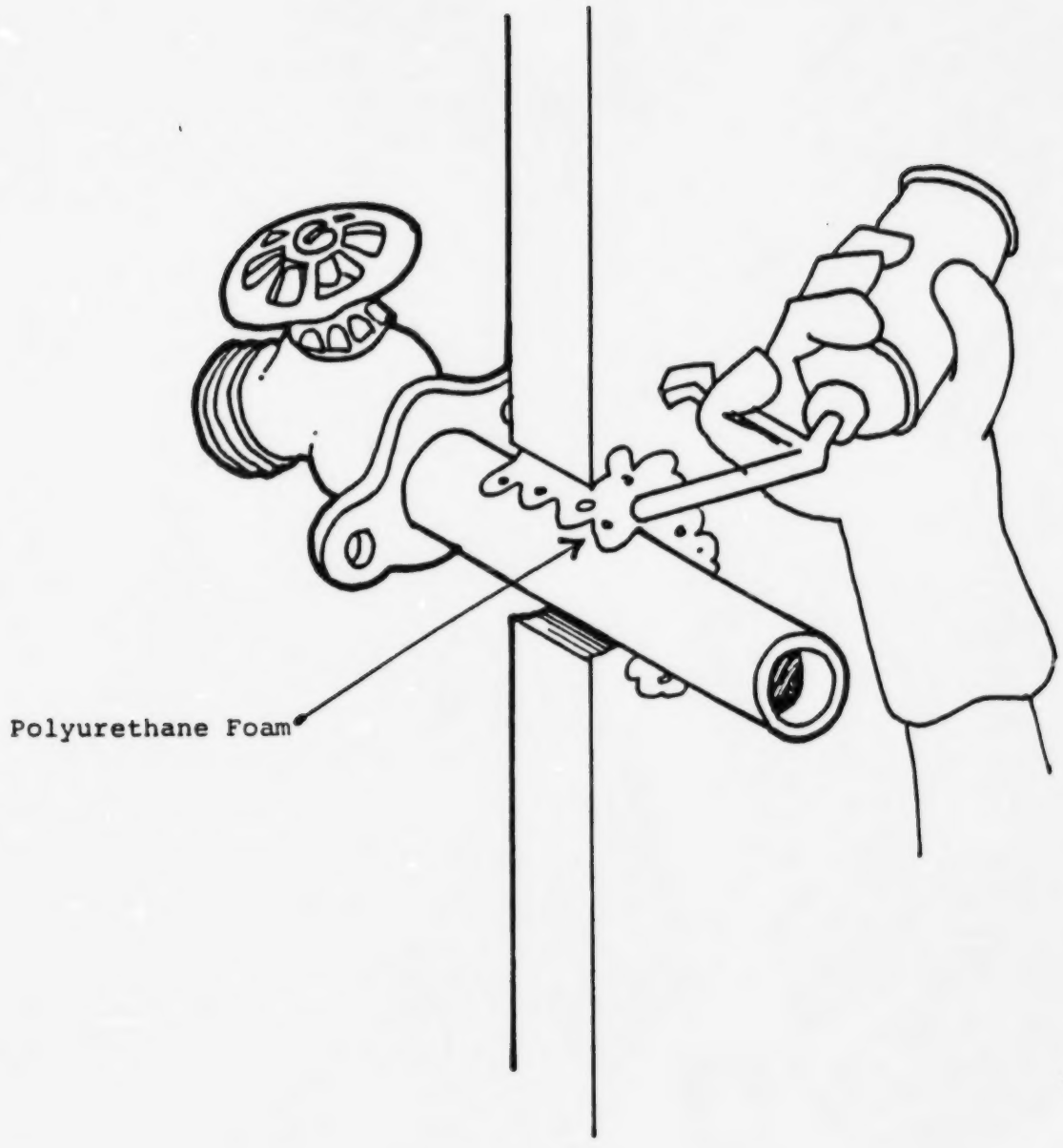


Figure 11 : Other Penetration Sealed with Foam

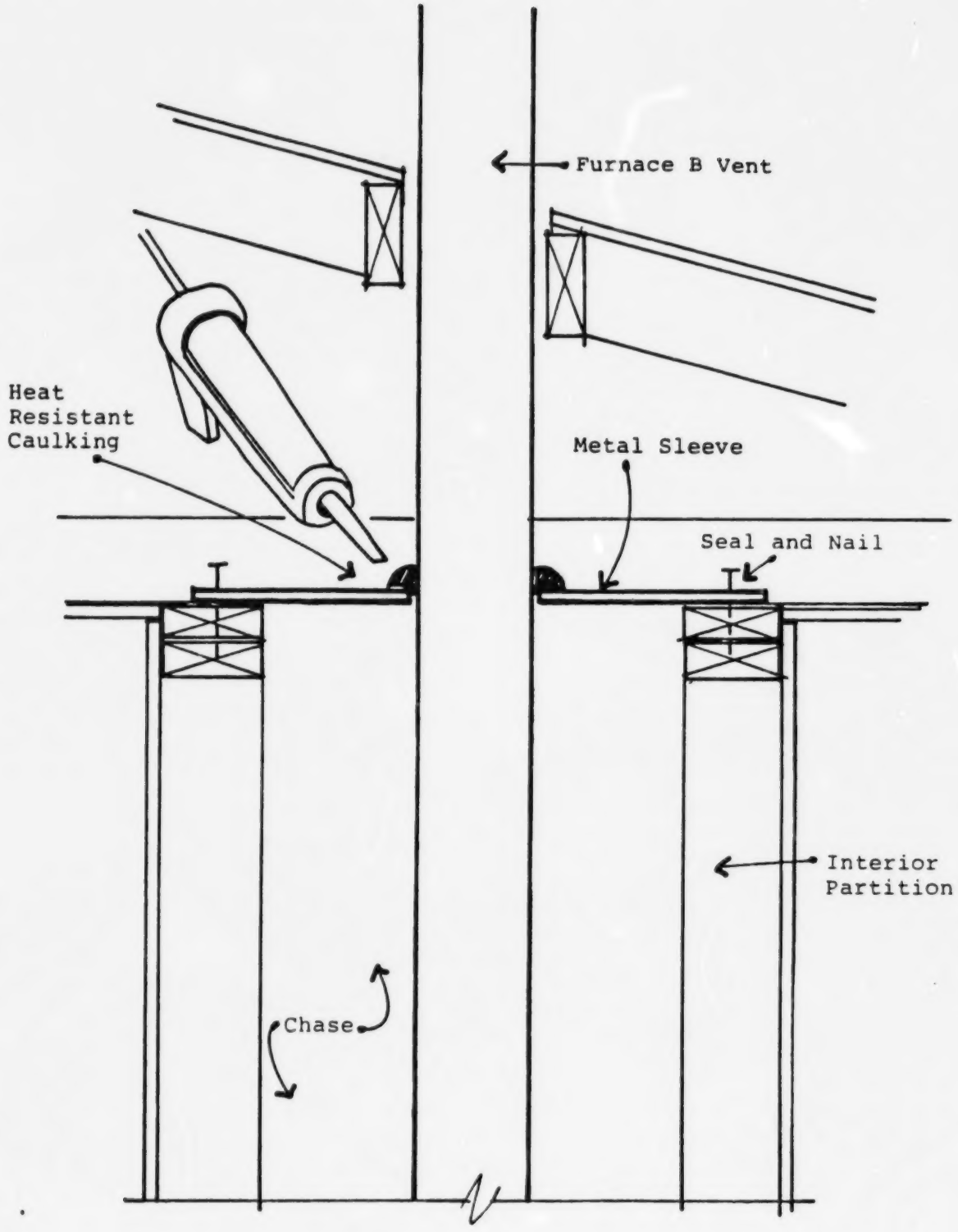


Figure 12 : Sealing Furnace Flue

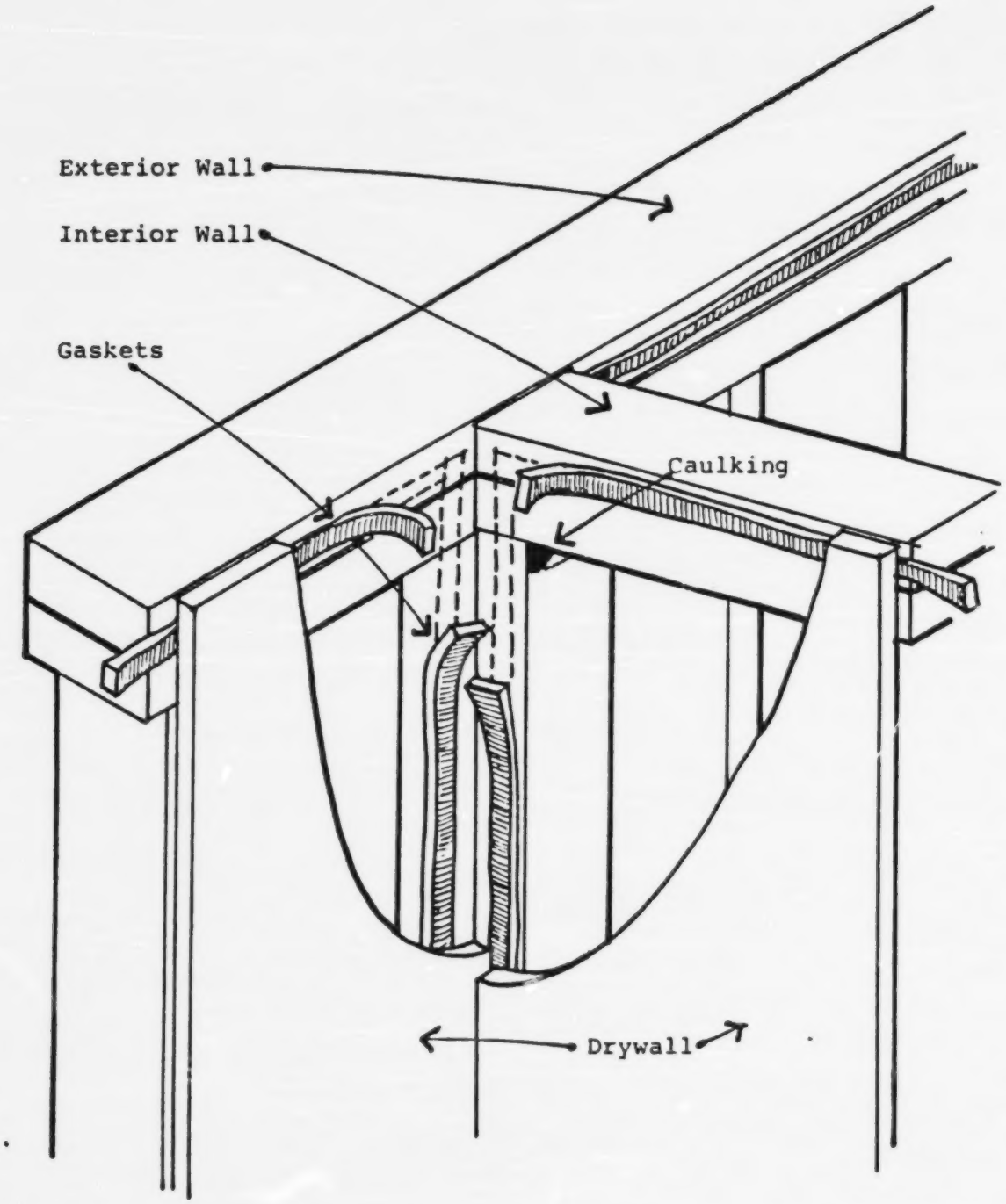


Figure 13 : Sealing Walls and Ceiling

5.1.4 Electrical Outlets

In the unit with the sealed polyethylene system, polyhats were installed around the electrical outlets and sealed with acoustical sealant (Figure 14 on page 36). The polyhats cost about $0.60 each.

Outlets in the unit using the ADA system were sealed with foam gaskets under the cover plate and with plug caps (Figure 15 on page 37). The cost was about $0.30 per outlet.

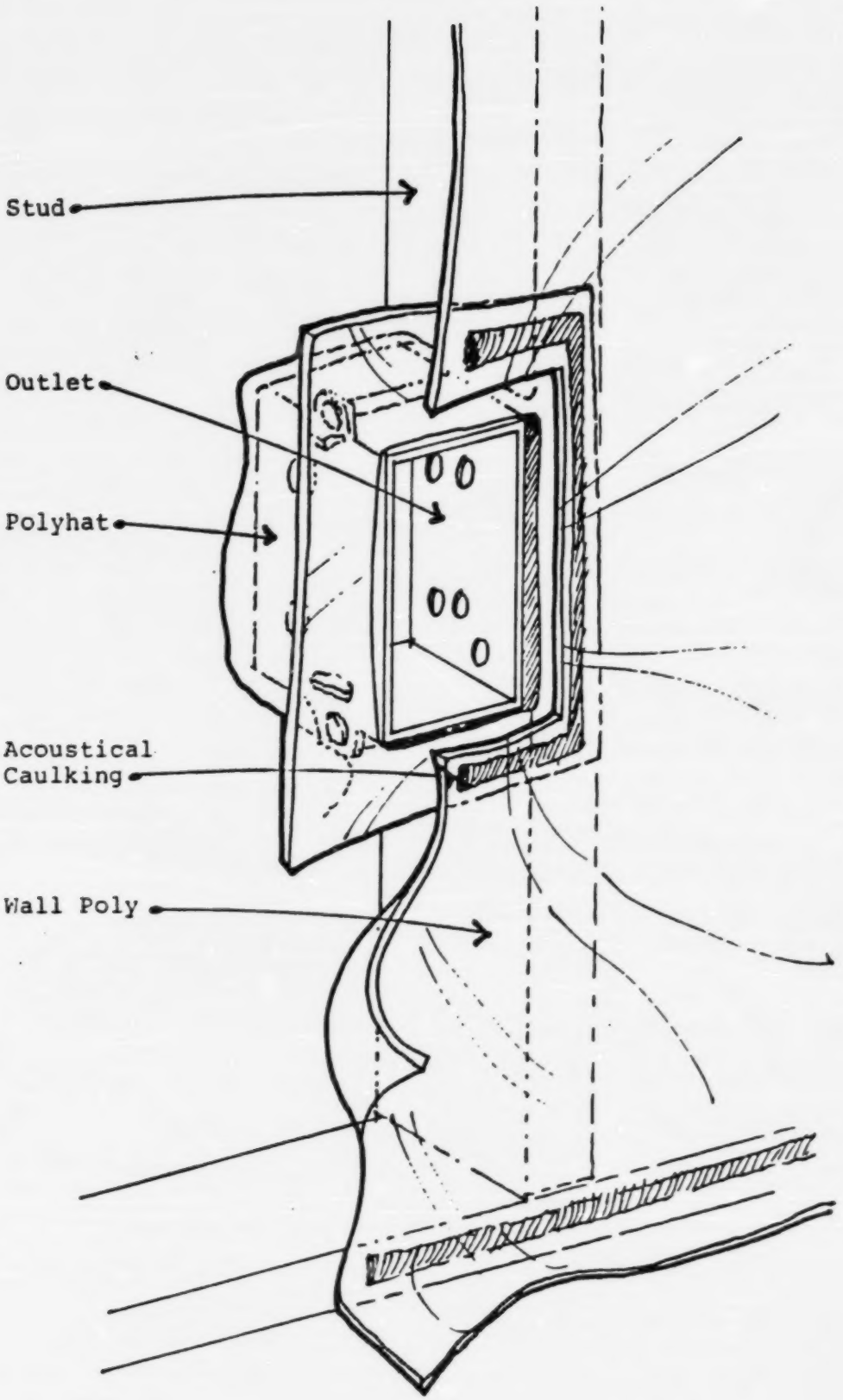


Figure 14 : Sealed Electrical Outlet - Polyhat

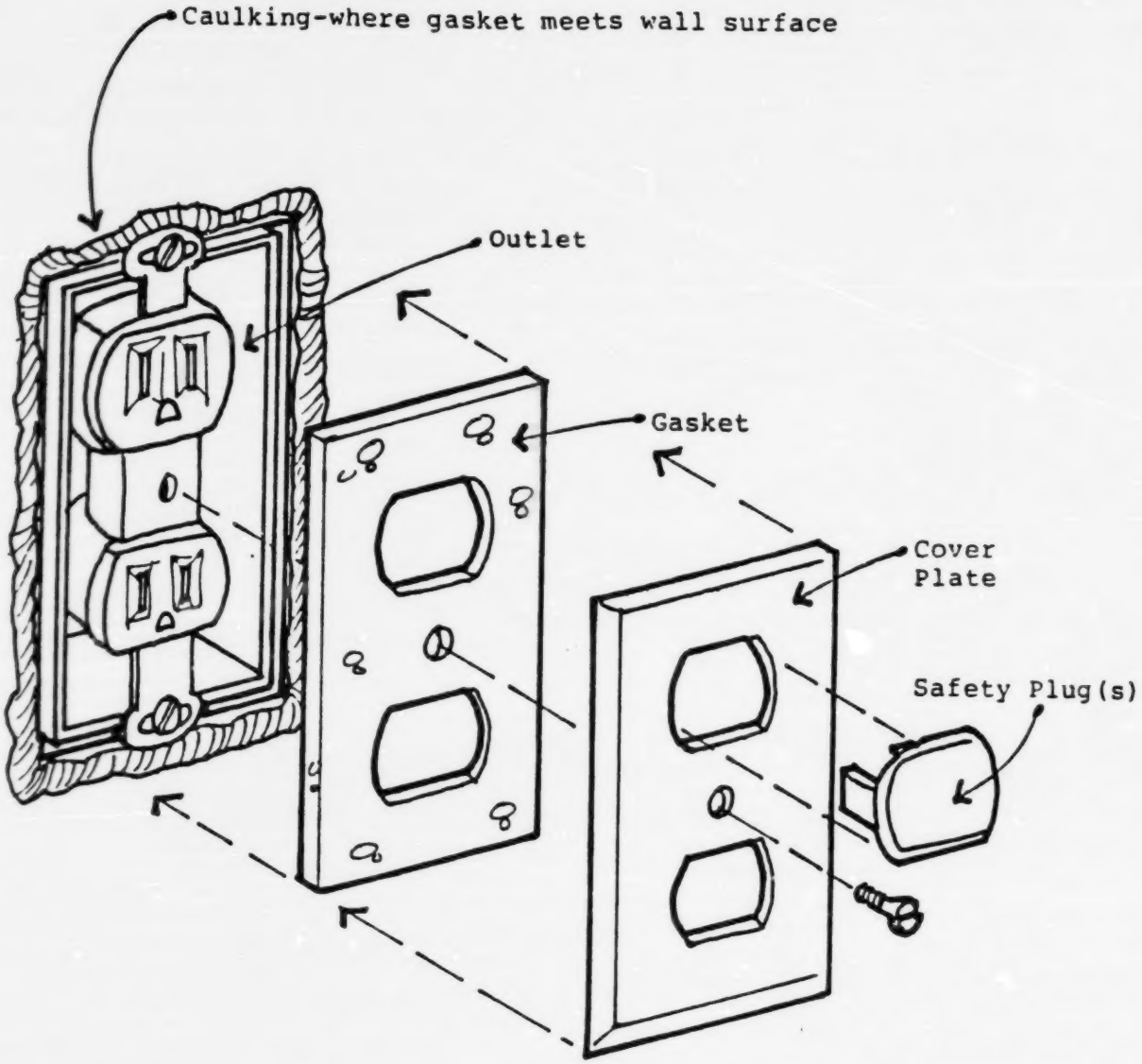


Figure 15 : Sealed Electrical Outlet - Gasket

5.1.5 Windows

Three techniques were used to seal around the windows:

a) polyethylene wrap;
b) polyethylene backer rod; and
c) spray applied foam.

a) *Polyethylene wrap (Figure 16 on page 40)*

This method was developed for use with the polyethylene system to ensure a continuous air/vapour barrier.

Installation Procedure:

A bead of acoustical caulking was applied to the window frame. A polyethylene strip 24 inches wide and about 20 inches longer than the distance around the window was then laid over the caulking bead and stapled into the bead. A pleat was made at the corners and acoustical sealant injected into the folds to seal the pleat. The pleats are necessary to allow the polyethylene around the window to be folded back onto the polyethylene on the walls and sealed.

Comments:

- This is the most involved of the three methods and requires experienced tradespersons to ensure it is installed correctly.
- Material cost is about $0.10 per lineal foot.
- Labour time is about 1/2 hour to seal 20 lineal feet.

b) *Polyethylene backer rod (Figure 17 on page 41)*

This method is used when windows are installed as delivered. The backer rod is available in diameters from 1/4 to 3 inches.

Installation Procedure:

The rough opening was loosely filled with fiberglass batt insulation and the backer rod was then wedged into the gap between the jamb and the rough opening to create an air seal. Whenever possible, a continuous length of backer rod was used to avoid any joint in the material.

Comments:

- o Different thicknesses of backer were necessary since the gap between the rough opening and the jamb varied from window to window.
- o Caulking may have to be applied at corners if the backer rod does not adequately seal this area.
- o Material cost is about $0.05 per lineal foot.
- o Labour time is about 10 minutes to seal 20 lineal feet.

c) Spray applied Foam (Figure 18 on page 42)

This product was also experimented with and used to seal a number of the pultruded fibreglass framed windows. These windows have a hollow molded window frame which is difficult to seal with the backer rod.

Installation Procedure:

The foam was sprayed in place between the jamb and the rough opening. The foam used on this job was an expanding type and, once it had set, excess foam was trimmed off.

Comments:

- o The foam expanded to over twice its applied volume and it was difficult to judge proper application rates. Once it had set, excess foam had to be trimmed off.
- o It was most suitable for larger gaps and difficult to apply in gaps less than 1/2 inch.
- o Non-expanding foams would be the easiest to work with and are available from commercial outlets.
- o Material cost is about $0.10 per lineal foot.
- o Labour time is about 20 minutes to seal and trim a 5 foot square window.

5.2 Vapour Diffusion Retarder

With the ADA system, regulatory authorities expressed concern about eliminating the polyethylene and using paint as a vapour diffusion retarder. They agreed to allow this procedure, however, if the permeance of the paints conformed to Type 2 vapour retarder requirements.

Based on work being carried out by the Alberta Research Council, gypsum board plus one coat of vapour retarder paint plus two coats of latex emulsion paint will provide a permeance of 44. This combination conforms to Type 2 vapour retarder requirements and was used on the CCDH. Insul-Aid paint by Glidden cost $25 per 4 Litres which compares to $15 per 4 Litres for standard latex paint.

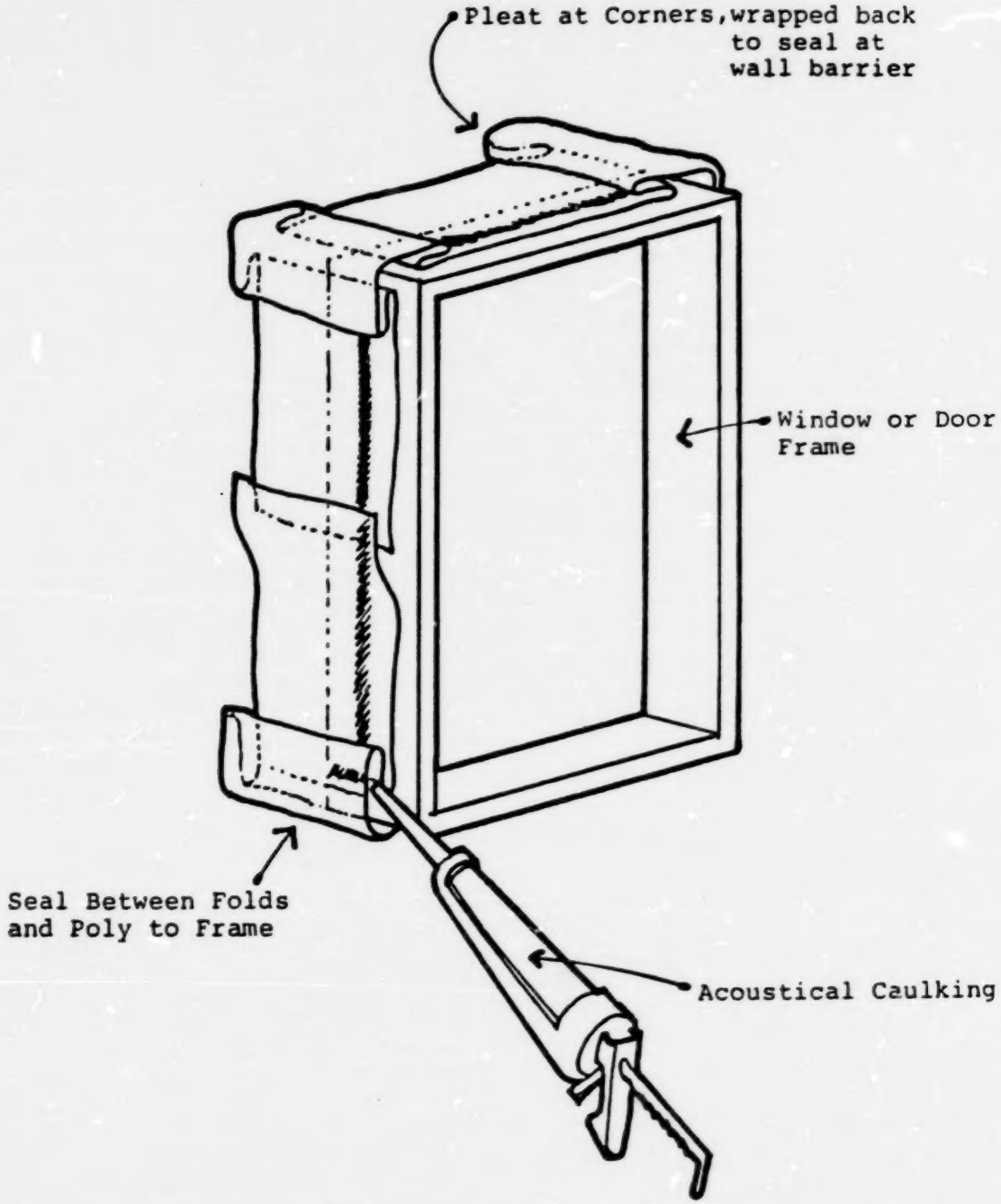

Pleat at Corners, wrapped back to seal at wall barrier
Window or Door Frame
Seal Between Folds and Poly to Frame
Acoustical Caulking

Figure 16 : Sealed Window _ Polywrap

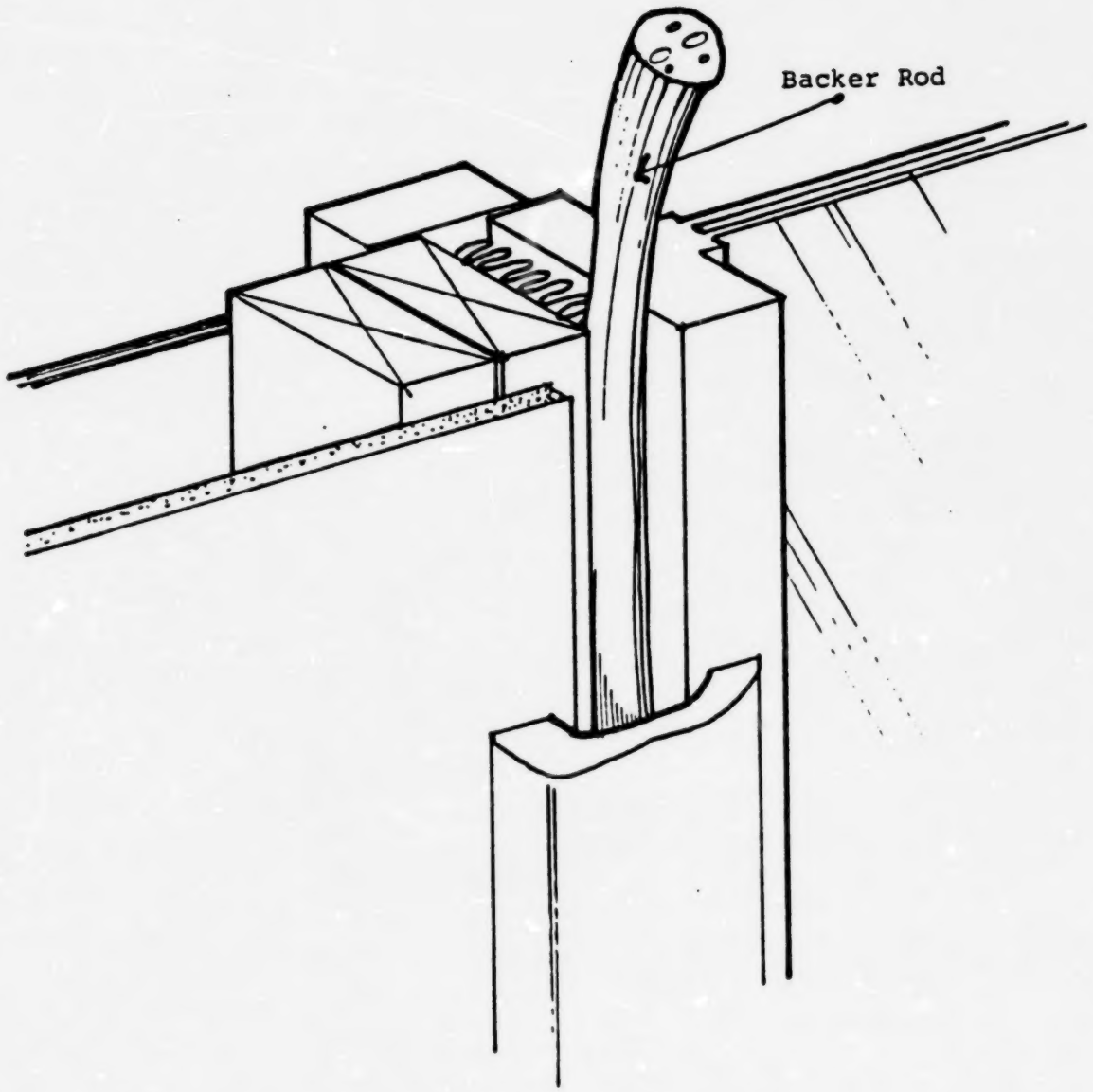


Figure 1.7 : Sealed Window - Backer Rod

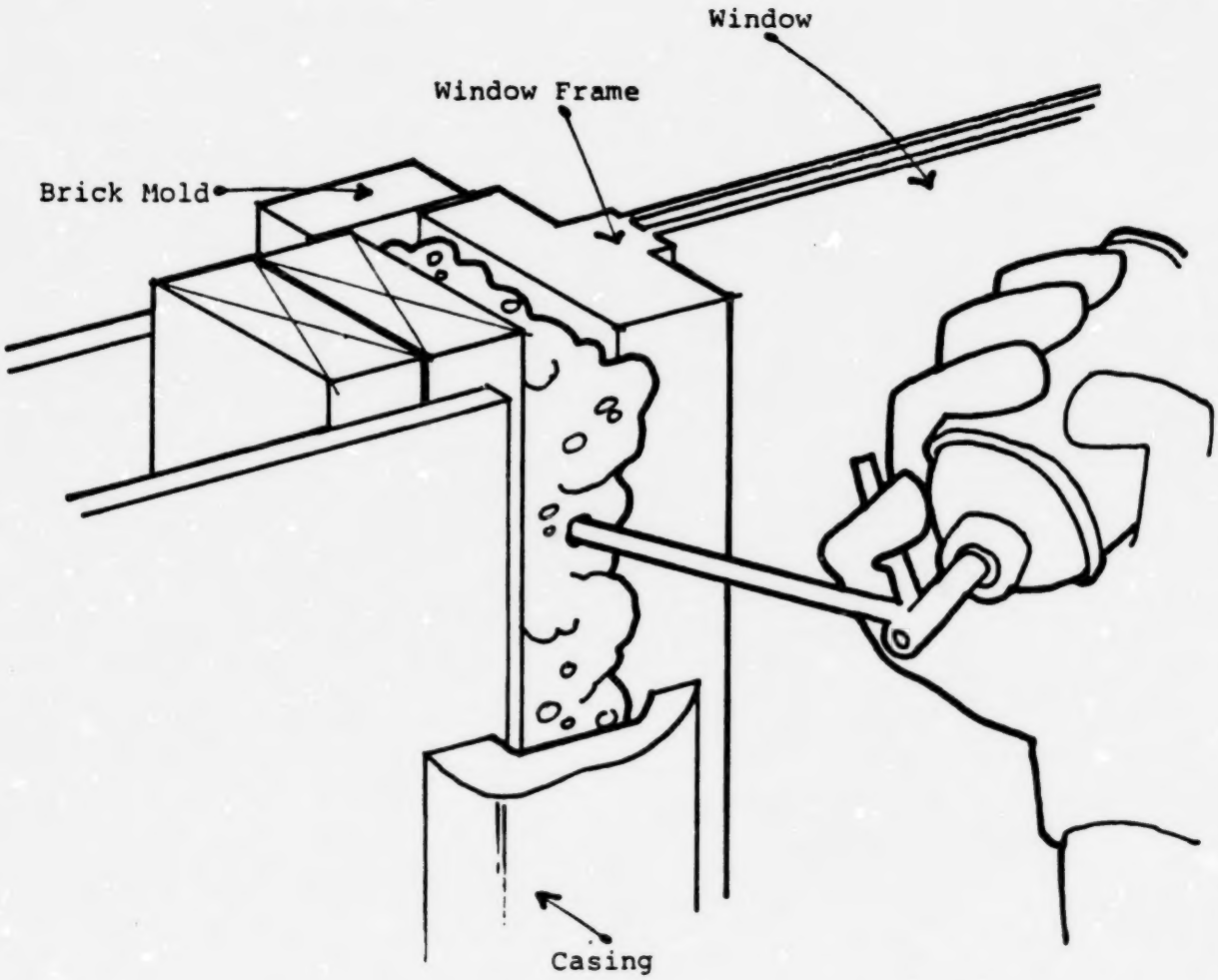


Figure 18 : Sealed Window - Spray Applied Foam

5.3 Incremental Costs

The total incremental costs for air-sealing each side of the CCDH can only be approximated due to the research nature of the facility and the fact that a number of different techniques were used on each side of the duplex. The following installed costs will, however, serve as a guideline for builders considering using any of the different air-sealing techniques previously described. Prices for a number of air-sealing techniques (the rim joist, for example) are estimated as if only that one technique were used. In this way, relative differences can be assessed. Hidden labour costs, such as the detailing and supervision required to install the various techniques, have not been included.

The CCDH has two 1000 ft2 bilevel units in which both levels have been fully developed. For the purpose of calculating the following incremental time and material costs, labour has been estimated at $10.00 per hour.

Walls and ceiling (3300 ft2)

Sealed polyethylene system over standard practices.	$170
ADA system over standard practices using vapour paint as the vapour retarder	$170
ADA system over standard practices using 2 mil polyethylene as the vapour retarder	$130
ADA system over standard practices using alkyd sealer as the vapour retarder	$ 70

Rim Joist (150 lineal ft)

Gasket plus rigid insulation	$160
Gasket plus plywood plus beadboard	$160
Membrane over entire area	$210
Membrane in two strips	$140

Windows (200 lineal ft)

Polyethylene wrap	$ 70
Backer rod	$ 30
Spray applied foam	$ 50

Building Envelope Penetrations ..... $ 20

Electrical $100

Note: Once the wiring is brought to the interior it remains to the inside by running over doorways and under the subfloor. Normally, circuits would return to, and continue along, the outside wall.

6.0 RECOMMENDED AIR-SEALING SYSTEM

During construction, experienced and knowledgeable builders and tradespeople are the key to successful air-sealing using the ADA or the sealed polyethylene systems. This experience is often not available, however, so techniques must be simple for installation by as few trades as possible. During the construction of the Cold Climate Demonstration House, ADA techniques proved to be more easily installed by the trades involved and to provide a more reliable air seal. In addition, the air-sealing products and techniques used in the ADA system satisfied all of the air barrier requirements specified in Section 2.2. Polyethylene, however, was found to be the preferred product for the vapour retarder amoung the trades involved.

The following materials and techniques for achieving an air barrier and vapour retarder have been recommended because they are cost effective and can be installed with a minimum of experience and with minimal involvement from the other subtrades. The incremental cost of providing an air/vapour barrier in a 1000 ft2 bilevel with both levels fully developed (as demonstrated with the CCDH) would be approximately $360. Figures illustrating recommended techniques are repeated in this section for easy reference.

Walls and ceiling

Frame in a conventional manner. Before the drywall is installed, apply the gaskets as shown in Figure 19 on page 46. The recommended gasket is a 1/2 inch wide by 1/4 inch thick saturated foam tape. One supplier is:

Preform Sealants, Inc.
18780 Cranwood Parkway
Warrensville Heights, Ohio 44128
(216) 587-6067

Rim joist

Frame in a conventional manner. Apply 2 strips of Bituthene Perm-A-Barrier membrane at the top and bottom of the rim joist as shown in Figures 20 and 21 on pages 47 and 48. Perm-A-Barrier is manufactured by W.R. Grace & Co. with offices across Canada. In Alberta:

W.R. Grace & Co.
14810 - 123 Avenue
Edmonton, Alberta T5L 2Y5

Windows and Doors

Backer rod is recommended for sealing around windows and doors (Figure 22 on page 49) and is best installed in one continuous piece. Care must be taken to seal the corners and it may be necessary to apply some caulking at those locations.

Electrical outlets

Install as few electrical outlets as possible on the exterior walls and the ceiling. Install foam gaskets under the cover plates and plugs in each outlet as shown in Figure 23 on page 50. A bead of silicone between the wall and the gasket will ensure a good seal. The gaskets are readily available at any building supply outlet.

Penetrations

Rubber gaskets (Figure 24 on page 51) and spray applied foam (Figure 25 on page 52) are recommended for sealing all penetrations through the building enclosure. Rubber gasket material is available through a plumbing supply outlet and spray applied foam through building suppliers. Non-expanding foam is more difficult to find but is usually available through a supplier of concrete accessories. Furnace flues should be sealed as in Figure 26 on page 53.

Vapour Retarder

Although the use of an alkyd sealer would appear to be the most effective method of providing a vapour retarder, it is not readily accepted by building inspectors. Until this changes, polyethylene is recommended for the vapour retarder (2 or 4 mil polyethylene is sufficient). Since it does not have to be continuous, it does not have to be sealed.

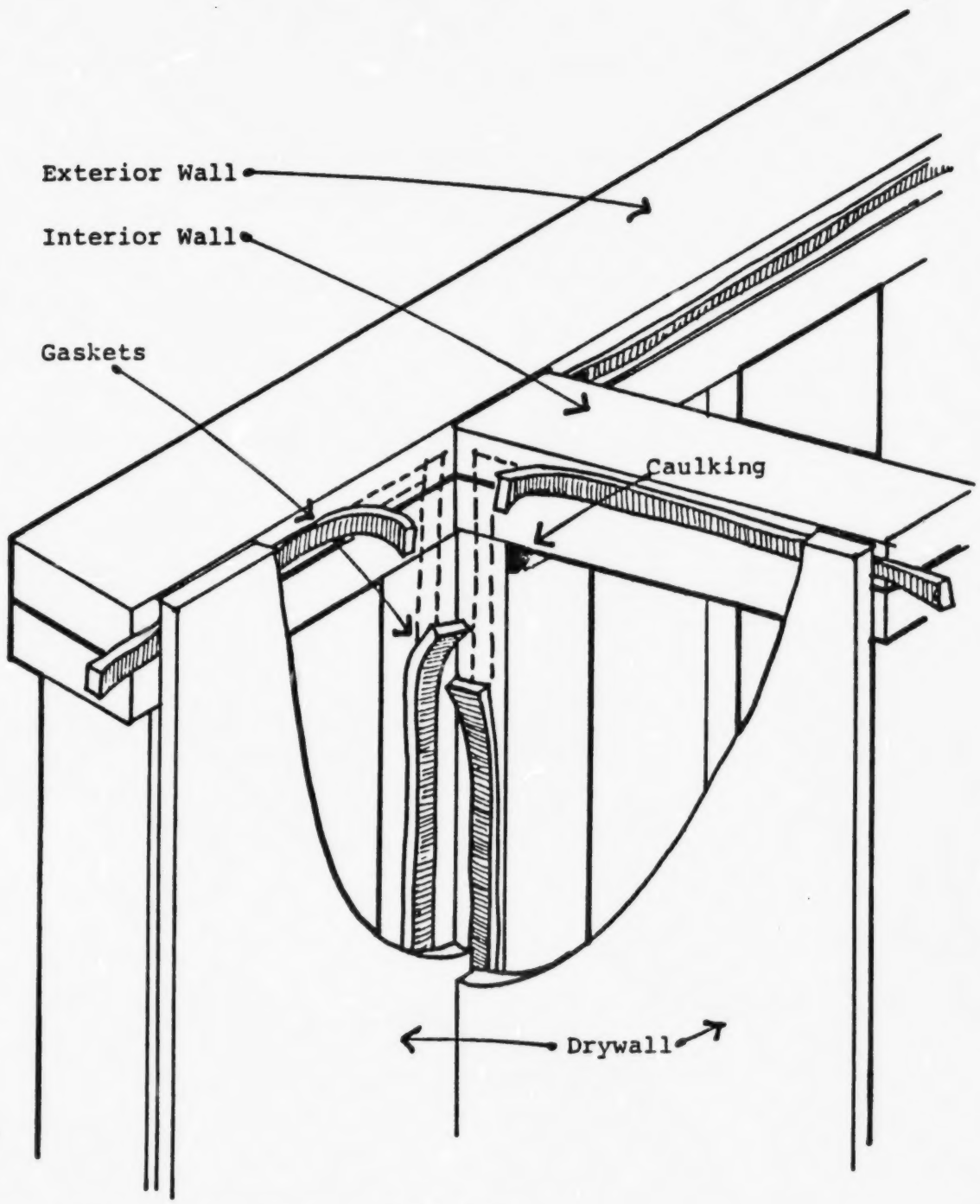


Figure 19 : Sealing Walls and Ceiling

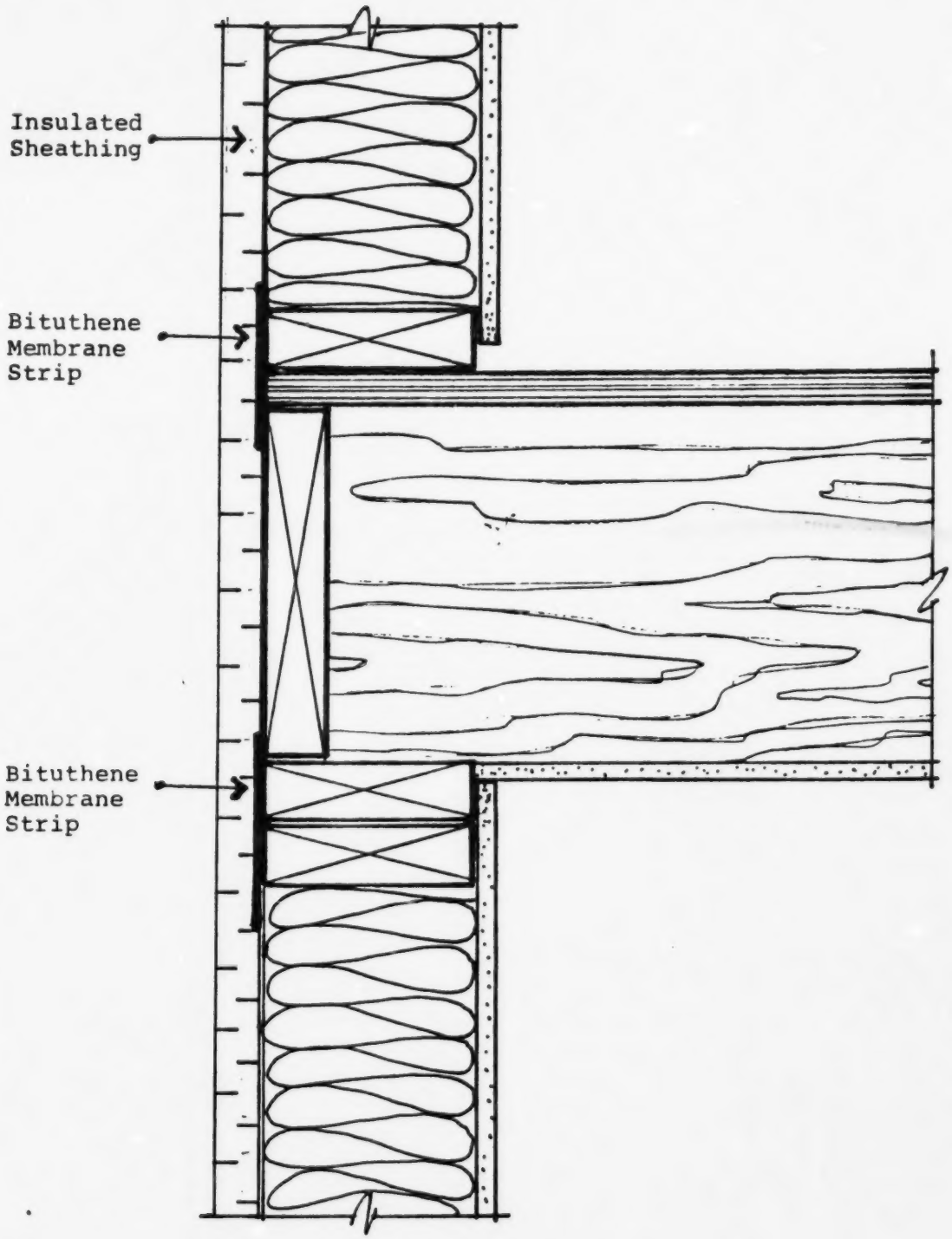


Figure 20: Alternate Membrane Application:
Wood Foundation and Second Storey

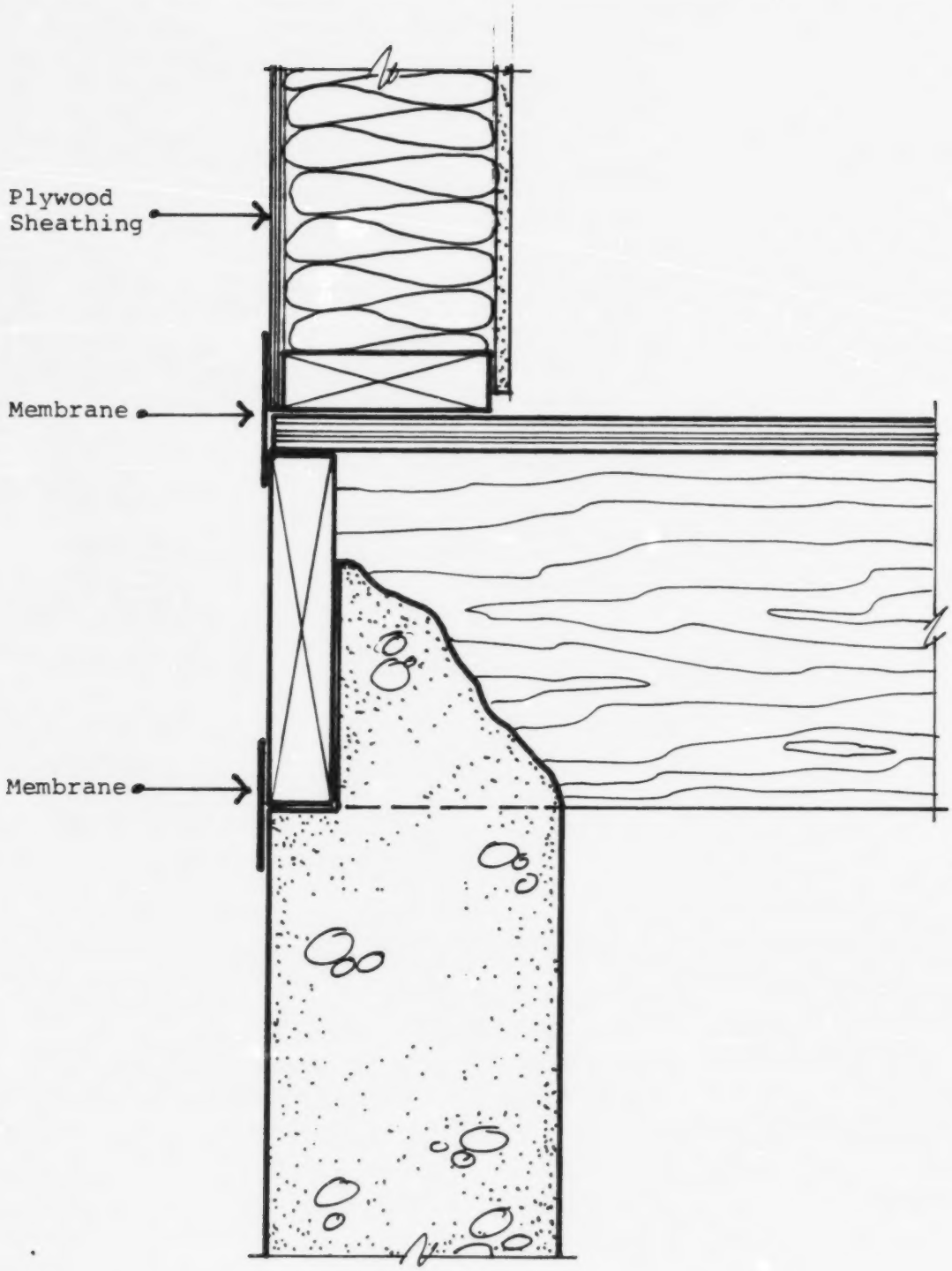


Figure 21: Alternate Membrane Application - Concrete Foundation

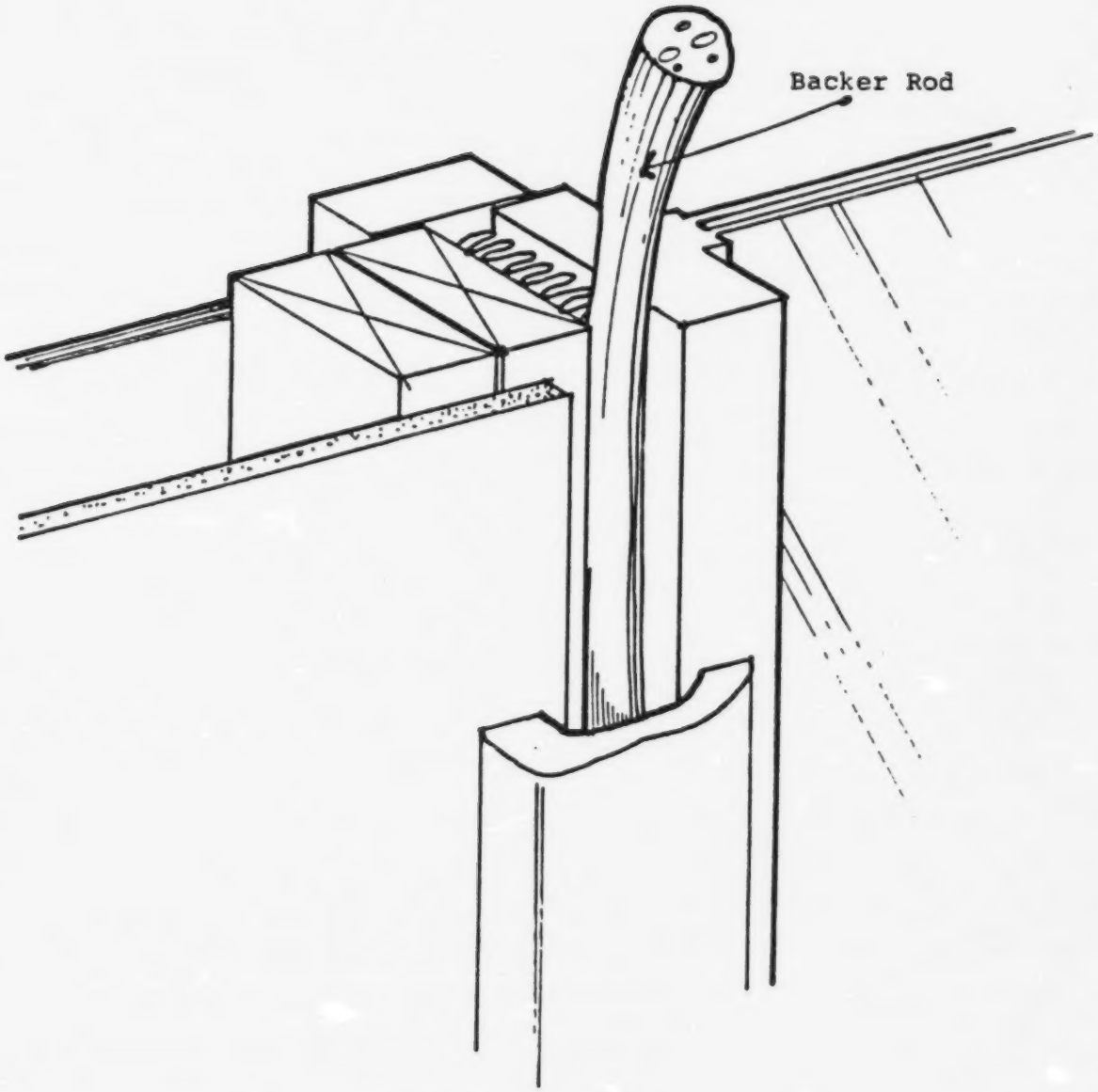


Figure 22: Sealed Window - Backer Rod

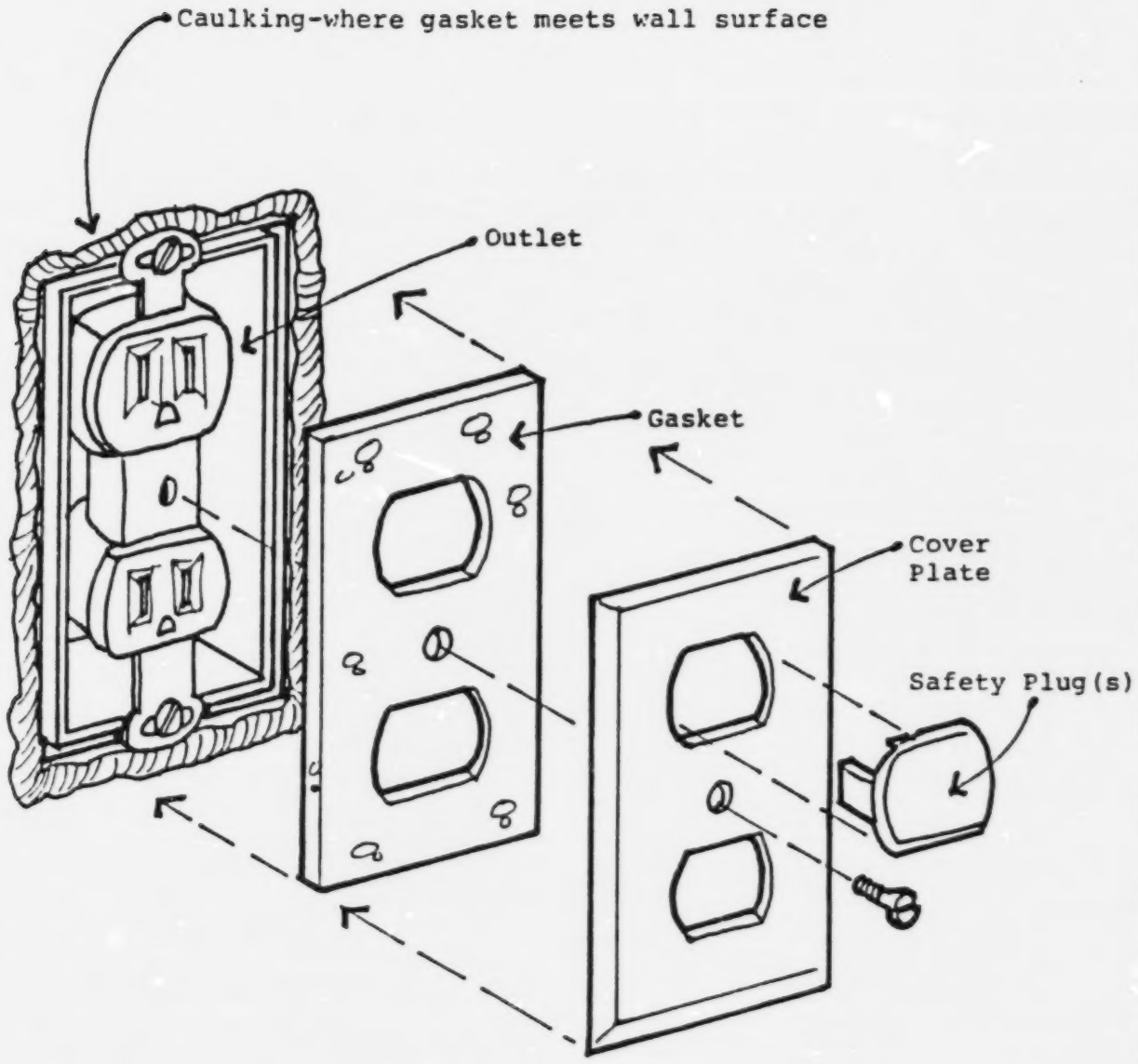


Figure 23 : Sealed Electrical Outlet

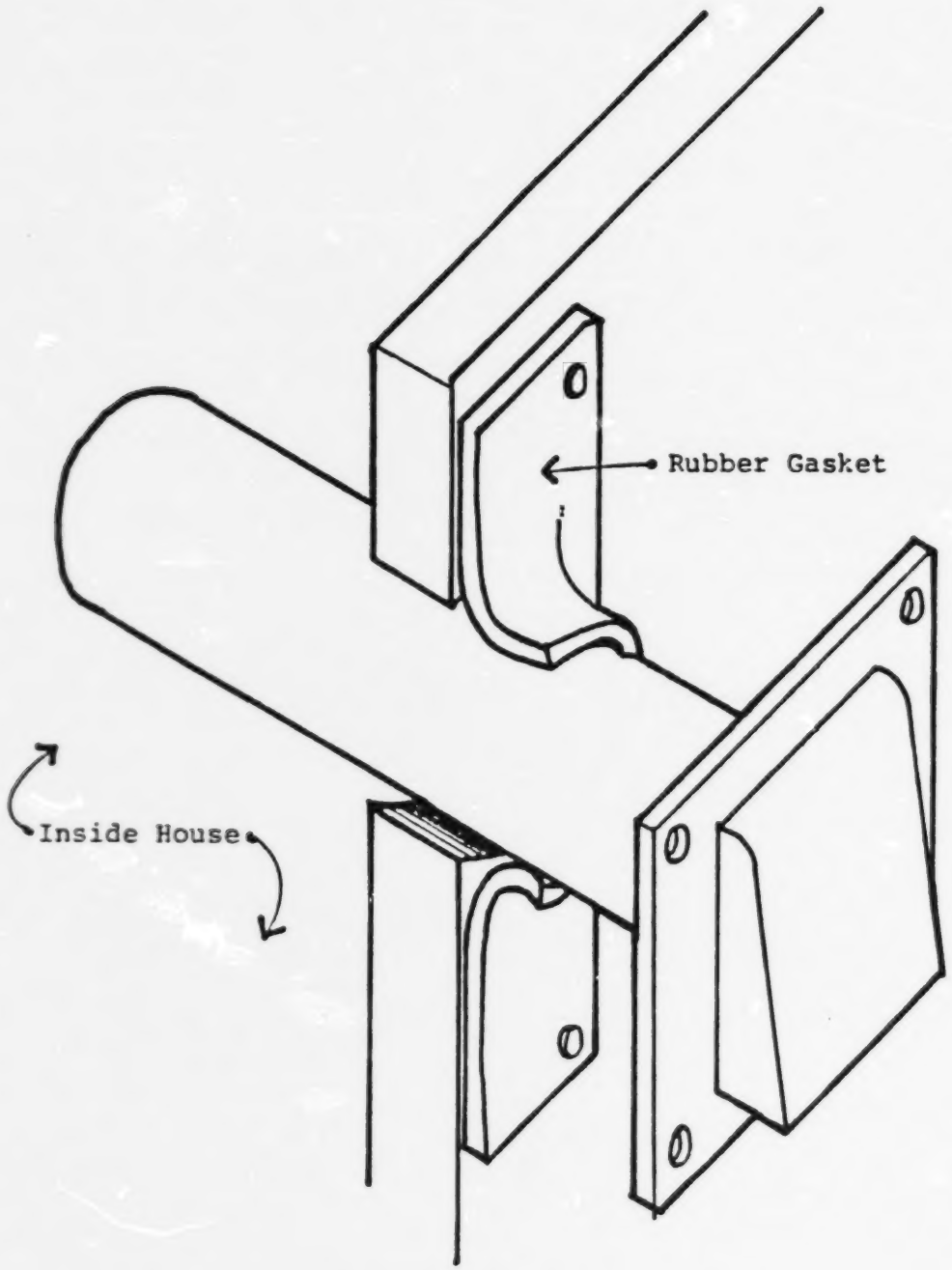


Figure 24 : Mechanical Duct Sealed with Rubber Gasket

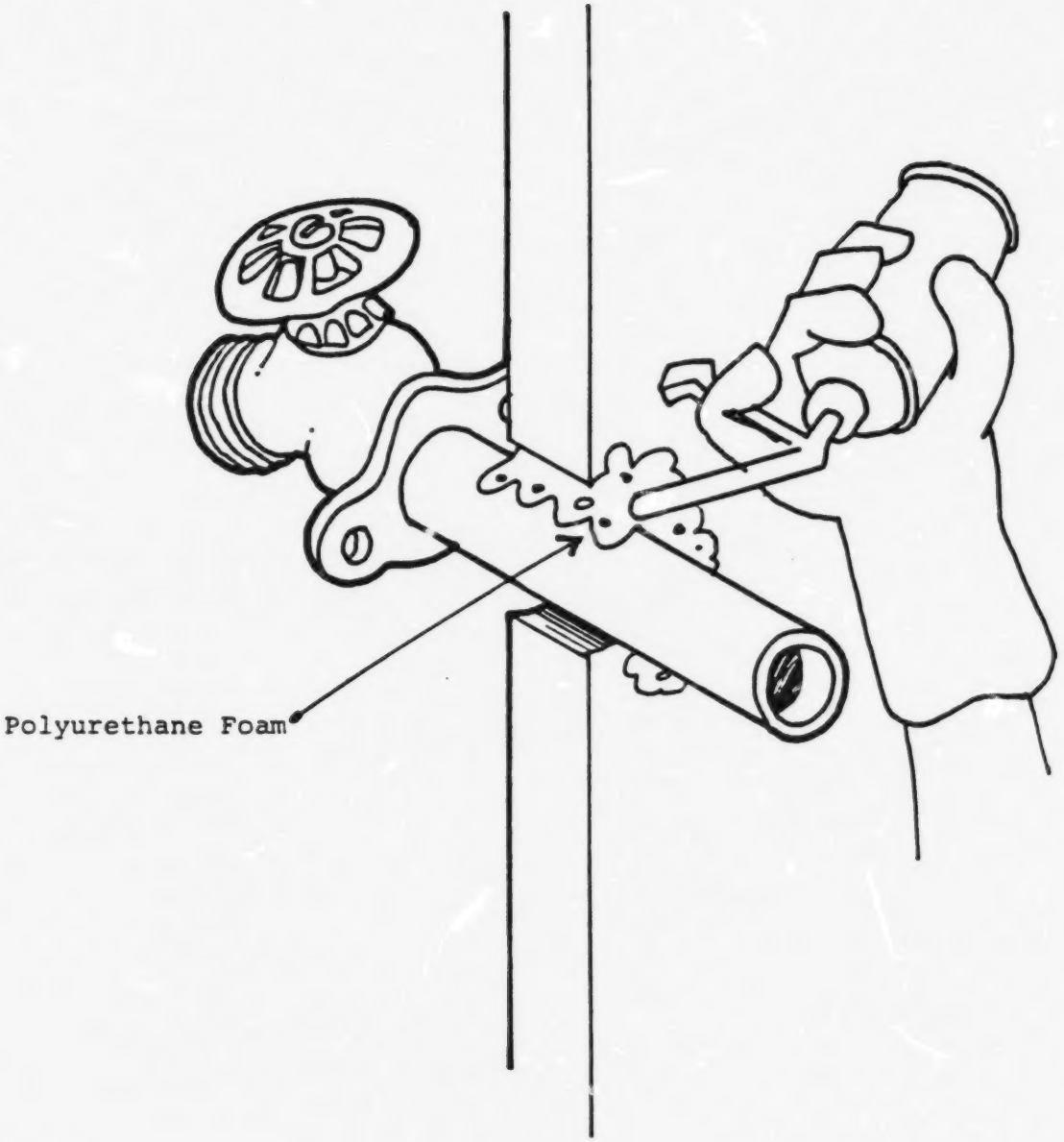


Figure 25 : Other Penetration Sealed with Foam

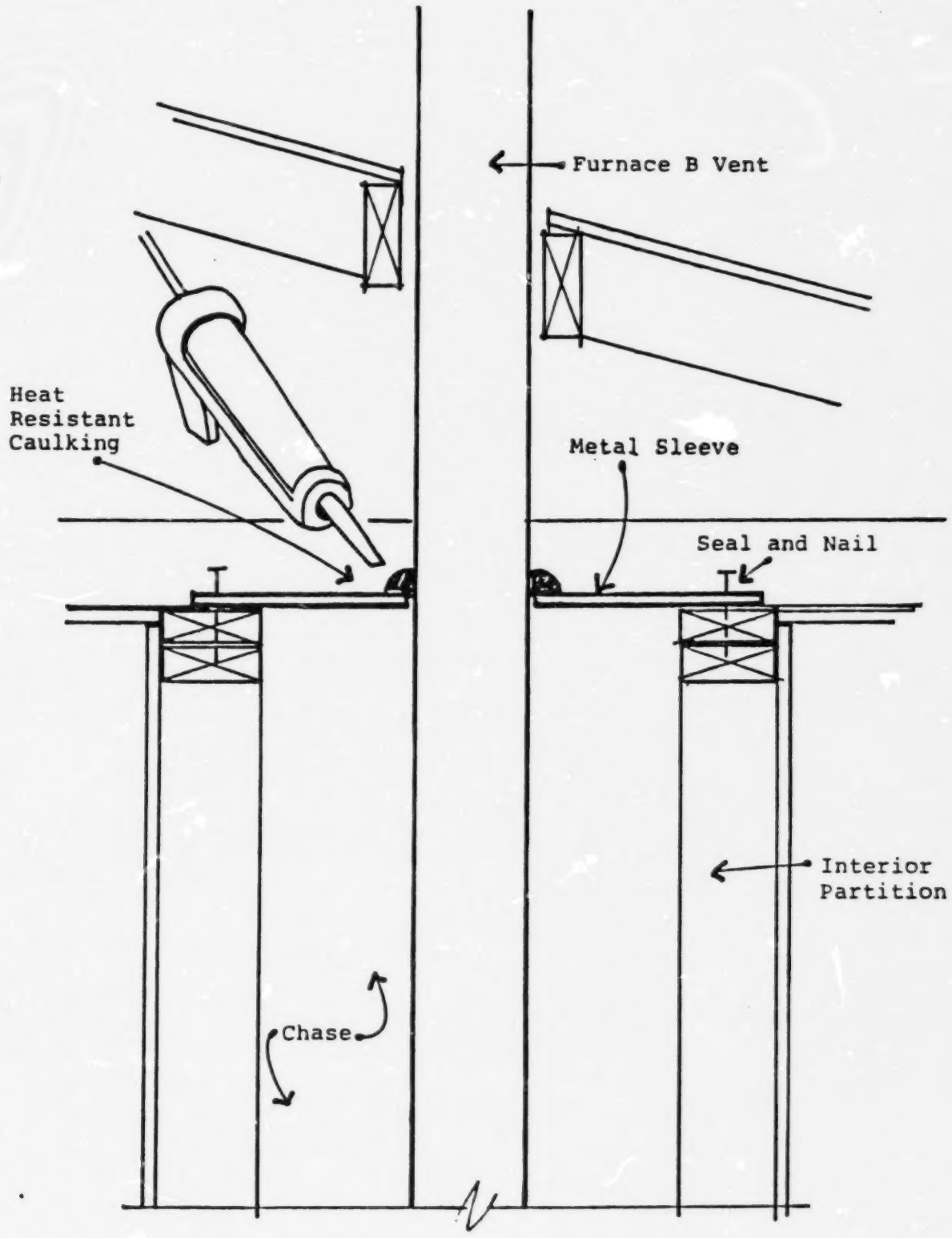


Figure 26 : Sealing Furnace Flue

7.0 CONCLUSIONS

Comprehensive air-sealing to significantly reduce air leakage is within the capability of all residential contractors, including major tract builders. Builders are not, however, using a pure ADA or sealed polyethylene system to accomplish this. They are combining features of both systems and developing hybrid systems that are easier to install and interfere as little as possible with the normal work of the other trades. The air-sealing system that is emerging is one in which the air-sealing materials can be installed in one trip by a single trade.

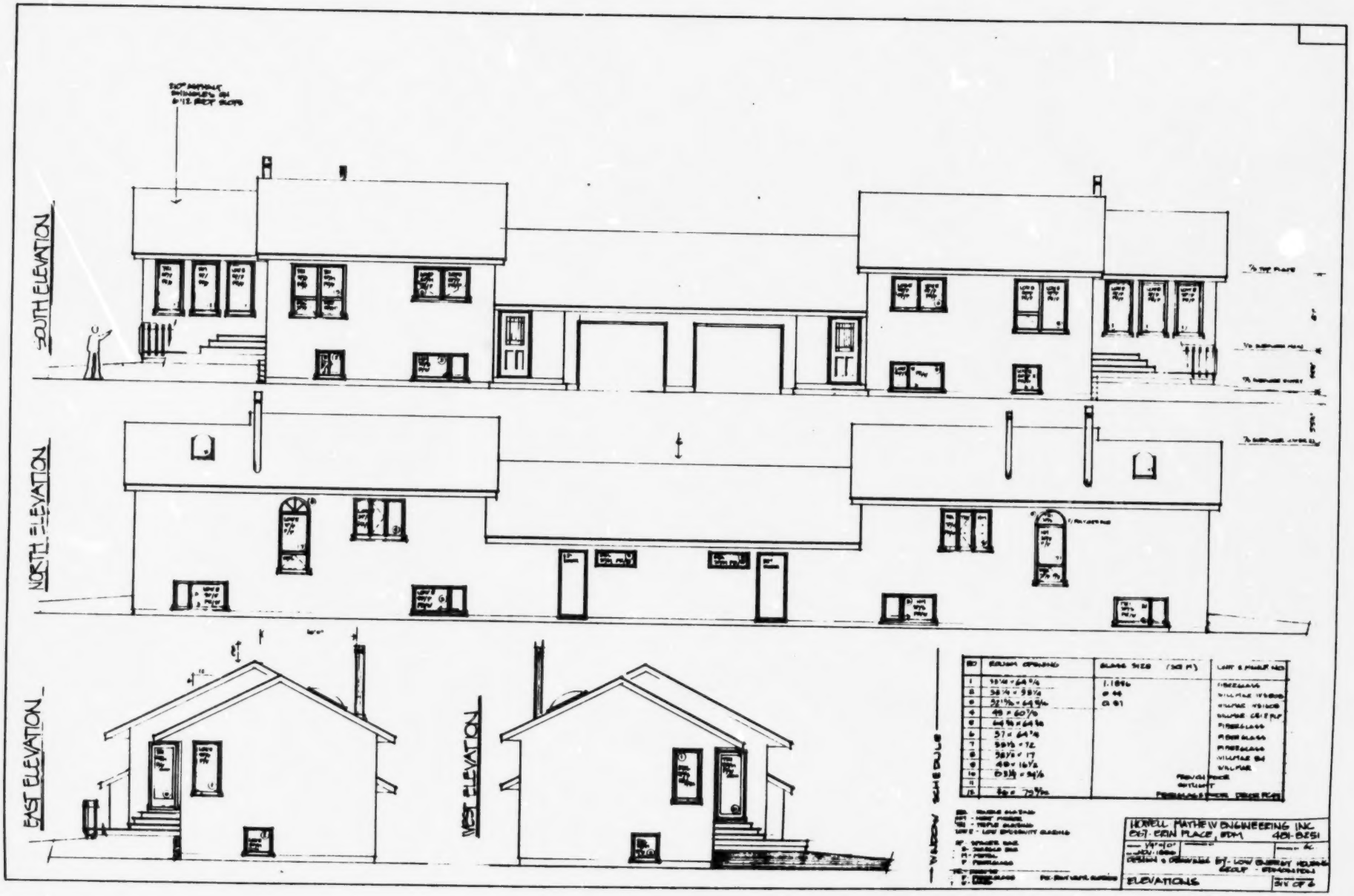
In addition to refining installation techniques, builders are experimenting with many different products to achieve an effective and durable air barrier and vapour retarder. The long term durability of many of the materials, and therefore the effectiveness of the air seal, remains in question, however, and additional testing and evaluation is recommended.

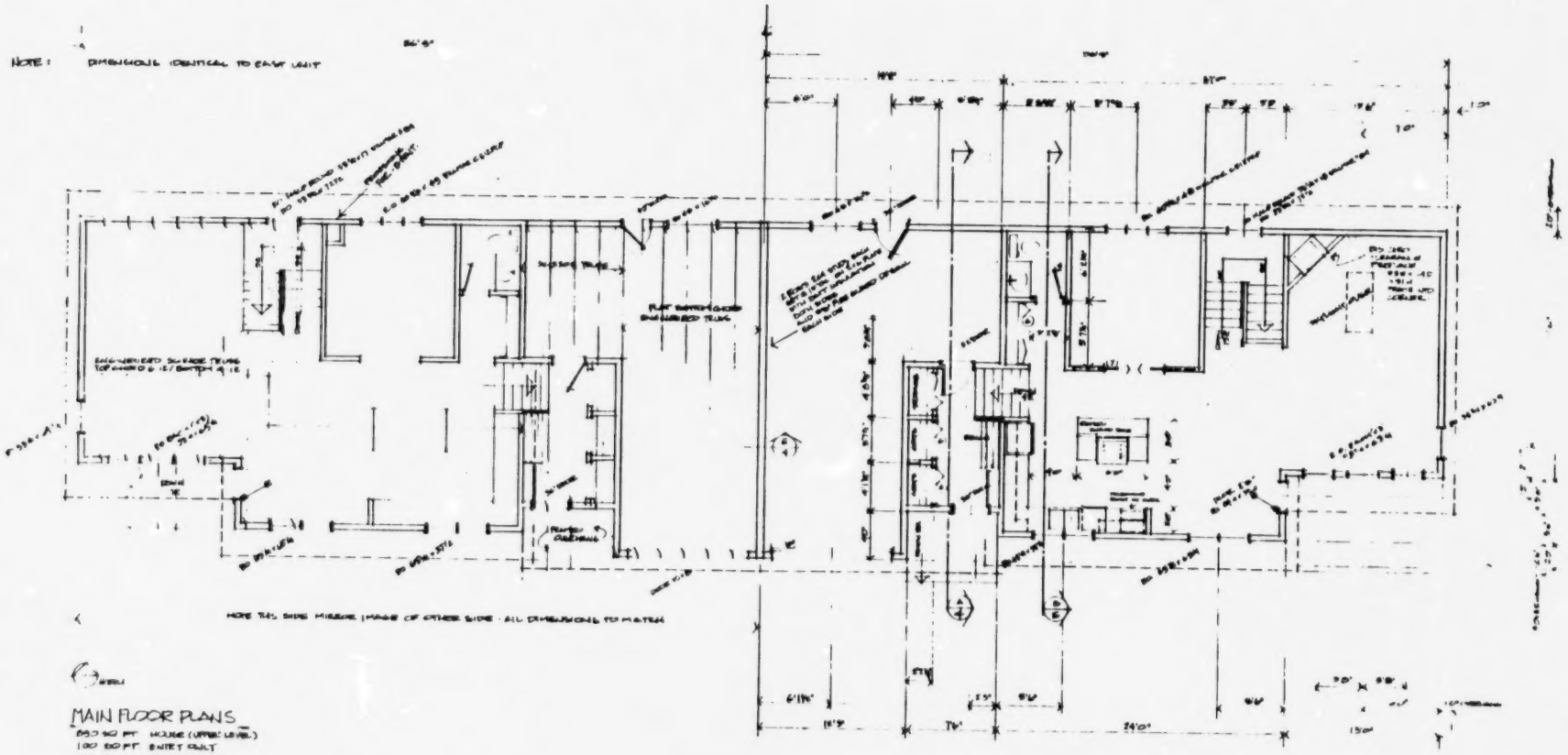
The incremental time and material costs required to achieve high levels of airtightness can be low but depend upon the complexity of the design, the method of application and the experience of the installers. As the design of the house becomes more complicated, a greater amount of management and supervisory time is expended to ensure that the air-sealing techniques used for a particular detail are properly designed and installed. Techniques used must be as simple as possible since the builder will usually be dealing with trades that have a poor understanding of, and are inexperienced in installing, air-sealing systems.

As building envelope airtightness increases, the amount of natural airchange that the house experiences decreases, and there is a greater potential for problems such as condensation, backdrafting and spillage of combustion appliances and the concentration of indoor air pollutants. Such problems can be successfully dealt with, however, by installing a controlled ventilation system and combustion appliances that are uncoupled from the effects of indoor air pressures. The technology to solve these problems is available but expensive. The high incremental cost of providing ventilation systems and induced draft or sealed combustion appliances is a major factor in reducing the builder's incentive to provide well-sealed housing.

APPENDIX A

DRAWINGS AND DESCRIPTION OF COLD CLIMATE DEMONSTRATION HOUSE


SOUTH ELEVATION
NORTH ELEVATION
EAST ELEVATION
WEST ELEVATION
HOWELL MATHEW ENGINEERING INC.
ELEVATIONS

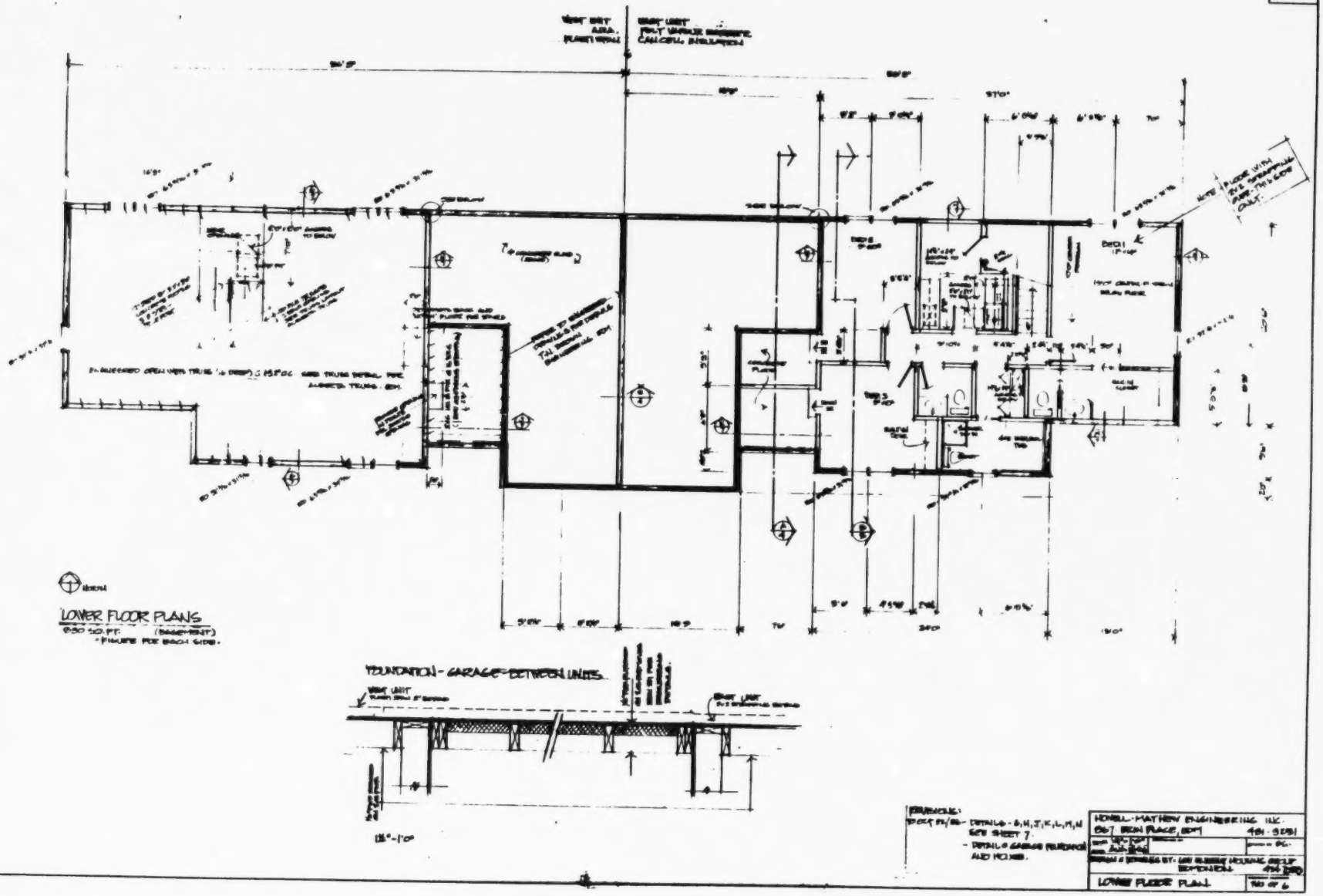


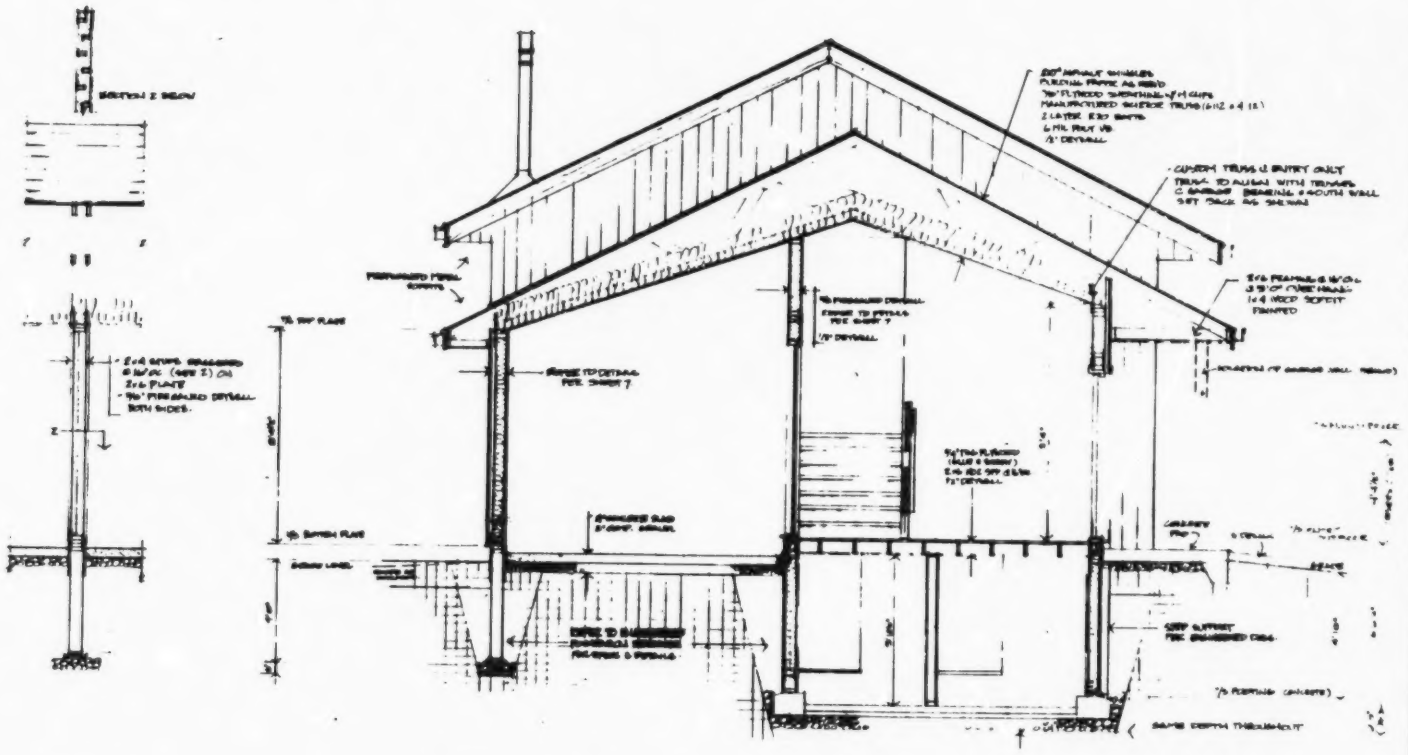
MAIN FLOOR PLANS

853.50 FT² HOUSE (UPPER LEVEL)
100.00 FT² ENTRY VAULT
414.50 FT² GARAGE ONLY
- FIGURED PER EACH SIDE -

REVISIONS:
TO CITY COPIES - SOUTH & REAR/WEST WINDOWS LIVING & REST. RELOCATED
- #3 FIREPLACE ADDED/ATTACHED / OUTSIDE WALL CUT
- FURNACE FROM ATTIC

HOWELL MATHEW ENGINEERING INC.
867 REIN PLACE, DEPT. 401-0761
DRAWN & DESIGNED BY: LORI PUSTAY HOWELL, AScT
MAIN FLOOR PLAN


LOWER FLOOR PLANS
FOUNDATION - GARAGE BETWEEN UNITS



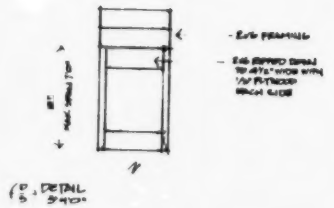
WALL SECTION

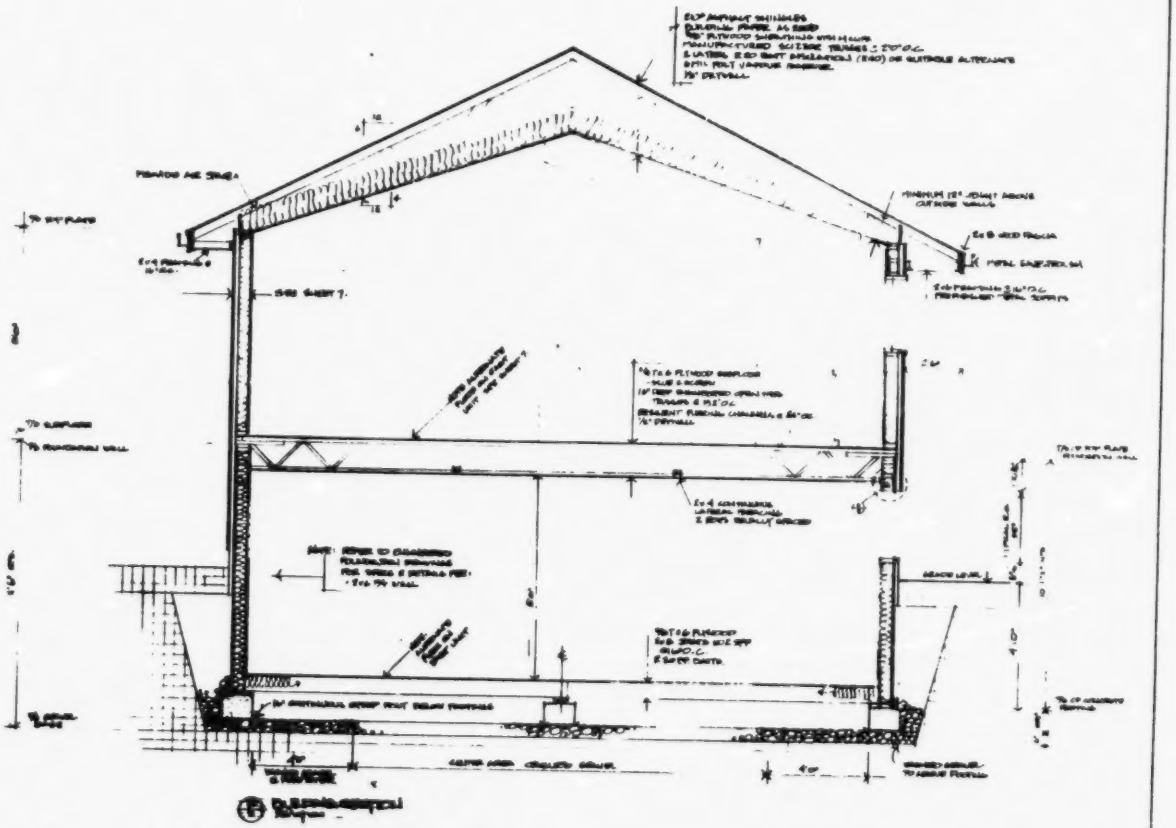
BUILDING SECTION

REVISIONS:

HOWELL-MATHEW ENGINEERING INC.

BUILDING SECTION - DETAILS





HOWELL · MATHEW · ENGINEERING INC.
617 MAIN PLACE, ESTT. 484-9261

BUILDING SECTION · DETAILS

1.0 BACKGROUND

As energy-efficient housing technology has developed, homes have become more complicated and expensive to build, maintain and operate. Concerns raised about their performance have made it apparent that:

a) houses must be designed, constructed and tested as an interrelated system of components - the building envelope, the internal layout, the heating and ventilating systems, the indoor environment and the occupants.

b) products and techniques used in the construction of these homes must be field tested and demonstrated for compatibility and use in cold climates.

c) a greater understanding of the building science principles governing moisture control, air quality, durability and affordability, system operation and energy conservation is required.

d) the building contractor and the trades require more extensive training and up-to-date information on technical changes within the industry in order to successfully build cost effective homes to existing standards of energy-efficiency.

The challenge facing research organizations and the housing industry is to address these concerns. Effective interaction and information transfer will be required between the numerous groups involved.

2.0 COLD CLIMATE DEMONSTRATION HOUSE

Howell Mayhew Engineering, Inc. (HME) is meeting this challenge through the design, construction, and operation of the Cold Climate Demonstration House (CCDH), a center that will serve to:

a) conduct multi-year research and monitoring projects;
b) field test and demonstrate new products and building techniques under controlled and actual house conditions;
c) upgrade existing and develop new technology;
d) transfer information and technology between basic and applied research organizations and the housing industry.

3.0 DESCRIPTION OF FACILITY

The CCDH was constructed as a bilevel duplex with the individual units separated by single car garages. One of the units is an occupied residence while the other provides office and seminar space. Both sides are used for research and product evaluation.

The facility has incorporated several different building and mechanical systems used in low energy housing. These are being evaluated in an effort to simplify the construction process for the building trades and the operation and maintenance of the house for the occupants. The CCDH was built and registered under the federal government's energy-efficient housing initiative, the R-2000 Program.

3.1 Building Components

a) Design and Internal Layout

Each unit covers only 990 square feet but has a fully developed lower level. This provides a large finished area while reducing the overall size and, therefore, the cost of the home. In this way, HME believes that energy-efficient housing can be made affordable for a wider range of homebuyers.

The lower level contains 3 bedrooms with walk-in closets, 2 1/2 bathrooms, and a mechanical/laundry room. Top chord bearing floor truss permit full 8 foot ceilings and large windows. Preserved wood foundations (PWF) and a suspended wood floor allow for increased insulation levels and maximum occupant comfort in this lower level area.

The main floor comprises a kitchen, dining room, living room, family room and bathroom. High heel scissor truss throughout provide high ceilings and allow for maximum insulation levels over the exterior walls. The entryway has been incorporated into the garage area.

High ceilings, an open design and the efficient use of space provide spaciousness to what would normally be considered a small home. The clear span truss eliminate the need for teleposts, beams and bearing walls on both levels permitting greater design flexibility.

b) Building Envelope

Test House

The PWF in this unit was insulated with fiberglass insulation. A diagonal strapping system manufactured by Plastispan was installed on the exterior, above grade portion. This system consists of diagonally grooved expanded polystyrene designed to accept flush mounted furring strips and allow any exterior finish to be easily and securely fastened. It is applied directly to the wall framing and eliminates the need for plywood sheathing.

The main floor walls are constructed with Plastispan's Thermo-Lock Wall Insulation system consisting of manufactured panels of expanded polystyrene with interlocking edges and grooves for 2 x 6 studs. Once installed, the studs protrude to the inside providing a 2 inch cavity for utilities. This space can be filled with batt insulation for additional R-value.

Occupied House

The PWF of this unit was insulated with a spray applied mixture of cellulose fibre insulation and water - no adhesive was necessary. A diagonal strapping system using Dow Styrofoam*, an extruded polystyrene, was attached to the exterior above grade portion.

The main floor walls were blown with dry cellulose fibre from the exterior. This was accomplished by securing the 10 mil polyethylene air/vapour barrier with 3/8 inch strapping installed vertically along each stud. The wall was blown prior to installing the drywall to allow a visual inspection of the stud cavities by regulatory authorities.

c) Windows

Triple glazed, low emmissivity, heat mirror and double glazed sealed units having either fiberglass, swiggle bar or metal spacers will be evaluated in windows frames of fiberglass, wood, PVC and vinyl clad. Fiberglass and metal insulated doors will also be evaluated.

d) Heating and Ventilating System

Test House

Forced air heating was installed in this unit. The system includes a combustion air line installed next to the furnace as well as a fresh air line connected

directly to the return air duct. This will facilitate the testing of different methods of supplying combustion air and the assessment of drafts associated with forced air systems having a fresh air line and operating on continuous low speed. This house presently has a Coleman medium-efficiency furnace and a Rheem induced draft water heater.

Occupied House

Radiant heating was installed in this unit. The hot water, radiant, in-floor system consists of polybutylene pipe running in a 1 1/2 inch cavity beneath the subfloor on both the main and lower floor levels. These cavities are also used to distribute fresh air throughout the house.

Provision has been made to accommodate the testing of both heat recovery and non-heat recovery ventilating systems.

e) Air Barrier

Reduced air leakage was achieved using an upgraded airtight drywall approach (ADA) in the demonstration unit and a hybrid polyethylene system in the occupied side. The upgraded technology was designed to improve the durability of each air barrier, simplify installation, and reduce costs.

3.2 Research and Testing

A computer-based monitoring system is installed in each unit of the facility. The research and testing program will investigate and demonstrate technology having the potential for being cost-effective and widely used in cold climate conditions. In addition to investigating building science concerns the facility will accommodate the field testing of new products such as furnaces, water heaters, windows, ventilating systems, integrated heating systems, and insulation systems. Manufacturers will be encouraged to test and demonstrate new technology in the CCDH in an effort to reduce the number of technical and installation problems that are occurring in the field.

Potential areas of research suited for this facility include:

i) Building Envelope
- o investigating wood moisture levels and envelope durability.
- o evaluating the performance of specific envelope

components such as windows, insulation, and air barriers.
- characterizing the house energy balance.

2) Mechanical Systems
- testing furnaces, water heaters and ventilators to evaluate efficiency, reliability, durability, installation procedures and cost-effectiveness.
- assessing backdrafting potential of combustion appliances.
- evaluating the performance of different heating and ventilating strategies with respect to fresh air and heat distribution, comfort, and costs.

3) Indoor Environment
- measuring and assessing air quality by determining pollutant sources and levels and investigating control strategies.
- investigating comfort levels by monitoring temperature distribution and relative humidity.

4) Occupant Effects
- detailing occupant lifestyle and attitudes including number of occupants, knowledge and care of system operation and maintenance and energy and water consumption patterns.

3.3 Information and Technology Transfer

The facility will also be used as a center for teaching and demonstrating the importance of an integrated approach to housing. The Alberta Home Builders' Association and NAIT plan to conduct R-2000 Builder Courses and House As A System Workshops here, while the Energy Conservation Branch of Alberta Energy intends to present housing industry seminars for groups involved in the different aspects of energy-efficient housing.